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U. S. DEPARTMENT OF AGRICULTURE

WEATHER BUREAU

CHARLES F. MARVIN, Chief

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# MONTHLY WEATHER REVIEW

VOLUME 45, No. 7

## JULY, 1917

WASHINGTON
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1917

# JULY, 1917.

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### NOTICE TO CONTRIBUTORS.

Contributions intended for publication in any given issue of the MONTHLY WEATHER REVIEW (e. g., January) should be in the hands of the editor before the end of the next following month (e. g., February), if no illustrations are required. When the paper is illustrated, the manuscript and the copy for illustrations must be submitted much earlier, in order to permit copy being prepared for the engraver by the end of the month.

REPRINTS are made up without covers in the original size and pagination of the REVIEW. They will not be furnished unless specifically REQUESTED WHEN THE MANUSCRIPT IS SUBMITTED.

# MONTHLY WEATHER REVIEW

CLEVELAND ABBE, jr., Editor.

VOL. 45, NO. 7
W. B. NO. 624.

JULY, 1917.

CLOSED SEPT. 4, 1917
ISSUED SEPT. 29, 1917

## INTRODUCTION.

As explained in this introduction during 1914, the MONTHLY WEATHER REVIEW now takes the place of the Bulletin of the Mount Weather Observatory and of the voluminous publication of the climatological service of the Weather Bureau. The MONTHLY WEATHER REVIEW contains contributions from the research staff of the Weather Bureau and also special contributions of a general character in any branch of meteorology and climatology.

SUPPLEMENTS TO THE MONTHLY WEATHER REVIEW are published from time to time.

The climatological service of the Weather Bureau is maintained in all its essential features, but its publications, so far as they relate to purely local conditions, are incorporated in the monthly reports "Climatological Data" for the respective States, Territories, and colonies.

Beginning August, 1915, the material for the MONTHLY WEATHER REVIEW has been prepared and classified in accordance with the following sections:

SECTION 1.—*Aerology.*—Data and discussions relative to the free atmosphere.

SECTION 2.—*General meteorology.*—Special contributions by any competent student bearing on any branch of meteorology and climatology, theoretical or otherwise.

SECTION 3.—*Forecasts and general conditions of the atmosphere.*

SECTION 4.—*Rivers and floods.*

SECTION 5.—*Seismology.*—Results of observations by Weather Bureau observers and others as reported to the Washington office.

SECTION 6.—*Bibliography.*—Recent additions to the Weather Bureau library; recent papers bearing on meteorology.

SECTION 7.—*Weather of the month.*—Summary of local weather conditions; climatological data from regular Weather Bureau stations; tables of accumulated and excessive precipitation: data furnished by the Canadian Meteorological Service; monthly charts Nos. 1, 2, 3, 4, 5, 6, 7, 8, the same as hitherto; Meteorological Summary and chart No. 9 of the North Atlantic Ocean for this month in 1916. Owing to the fact that ocean meteorological data are frequently not available for a considerable time after the close of the month to which they relate, the chart and text matter in connection therewith appear one year late.

In general, appropriate officials prepare the seven sections above enumerated; but *all students of atmospherics are cordially invited to contribute such additional articles as seem to be of value.*

The voluminous tables of data and text relative to local climatological conditions, that during recent years were prepared by the 12 respective "district editors," are omitted from the MONTHLY WEATHER REVIEW, but collected and published by States at selected section centers.

The data needed in Section 7 can only be collected and prepared several weeks after the close of the month designated on the title-page; hence the REVIEW as a whole can only issue from the press within about eight weeks from the end of that month.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are specially due to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belén College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

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The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but such publication is not to be construed as official approval of the views expressed.

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## CORRIGENDA.

REVIEW, June, 1917:

Page 272, column 1, supply the list of precipitation rates at New Haven, as follows:

| | Inch. |
|---|---|
| March 11, 10 p. m. to 12th, 7 a. m. | 0.10 |
| March 12, 7 a. m. to 12th, 3 p. m. | 0.14 |
| March 12, 3 p. m. to 12th, 10 p. m. | 0.11 |
| March 12, 10 p. m. to 13th, 7 a. m. | 0.07 |

Page 331, Table II, Milwaukee, Wis., "Excessive rates ended" *for* 1.25 *read* 1:25;
12.47 *read* 12:47;
1.37 *read* 1:37;
2.47 *read* 2:27.

# SECTION I.—AEROLOGY.

## SOLAR AND SKY RADIATION MEASUREMENTS DURING JULY, 1917.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Washington, D. C., Aug. 28, 1917.]

For a description of instrumental exposures and an account of the methods of obtaining and reducing the measurements, the reader is referred to the MONTHLY WEATHER REVIEW for January, 1917, **45**:2.

The monthly means and departures from normal values, given in Table 1, show that direct solar radiation averaged close to normal intensity at all the stations. Noon intensities of 1.39 gram-calories at Madison on the 10th and of 1.44 at Lincoln on the 11th, exceed by about 2 per cent the previous maximum July noon intensities at those stations.

Table 3 shows only unimportant departures from normal radiation at Madison, but a deficiency of nearly 16 per cent at Washington.

Skylight polarization measurements were obtained at Washington on only two days, and give a mean of 40 per cent. The measurements at Madison give a mean of 59 per cent, with a maximum of 71 per cent on the 2d. This latter is unusually high for July.

TABLE 1.—*Solar radiation intensities during July, 1917.*

[Gram-calories per minute per square centimeter of normal surface.]

**Washington, D. C.**

| Date. | Sun's zenith distance. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.0° | 48.3° | 60.0° | 66.5° | 70.7° | 73.6° | 75.7° | 77.4° | 78.7° | 79.8° |
| | Air mass. | | | | | | | | | |
| | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 |
| A. M. | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* |
| July 2 | ..... | 1.08 | 0.94 | 0.80 | 0.69 | ..... | ..... | ..... | ..... | ..... |
| 17 | ..... | 1.01 | 0.92 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 28 | 1.32 | 1.27 | 1.18 | 1.10 | 1.01 | 0.96 | 0.90 | 0.84 | 0.78 | 0.73 |
| 30 | 1.20 | 1.08 | 0.87 | 0.79 | 0.72 | ..... | ..... | ..... | ..... | ..... |
| 31 | 1.27 | 1.13 | 1.00 | 0.89 | 0.82 | 0.75 | ..... | ..... | 0.59 | 0.52 |
| Monthly means | 1.26 | 1.11 | 0.98 | 0.90 | 0.81 | (0.86) | (0.90) | (0.84) | (0.68) | (0.62) |
| Departure from 9-year normal | ±0.00 | −0.01 | −0.01 | −0.01 | −0.06 | +0.07 | +0.20 | +0.14 | +0.07 | ..... |
| P. M. | | | | | | | | | | |
| July 28 | ..... | 1.17 | 1.05 | 0.95 | 0.86 | ..... | ..... | ..... | ..... | ..... |
| 31 | ..... | 1.01 | 0.94 | 0.84 | 0.71 | 0.61 | ..... | ..... | ..... | ..... |
| Monthly means | ..... | (1.09) | (1.00) | (0.90) | (0.78) | (0.61) | ..... | ..... | ..... | ..... |
| Departure from 9-year normal | ..... | +0.04 | ±0.00 | +0.03 | −0.02 | −0.15 | ..... | ..... | ..... | ..... |

TABLE 1.—*Solar radiation intensities during July, 1917*—Continued.

**Madison, Wis.**

| Date. | Sun's zenith distance. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.0° | 48.3° | 60.0° | 66.5° | 70.7° | 73.6° | 75.7° | 77.4° | 78.7° | 79.8° |
| | Air mass. | | | | | | | | | |
| | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 |
| A. M. | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* |
| July 3 | ..... | ..... | ..... | ..... | 1.03 | ..... | ..... | ..... | ..... | ..... |
| 4 | ..... | ..... | 1.17 | 1.10 | 1.04 | ..... | ..... | ..... | ..... | ..... |
| 8 | ..... | ..... | 0.87 | 0.75 | ..... | ..... | ..... | ..... | ..... | ..... |
| 9 | 1.39 | 1.23 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 10 | 1.40 | ..... | 1.20 | 1.12 | ..... | ..... | ..... | ..... | ..... | ..... |
| 12 | ..... | ..... | 1.17 | 1.07 | 0.98 | 0.90 | 0.83 | ..... | ..... | ..... |
| 13 | 1.36 | 1.25 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 14 | 1.38 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 15 | ..... | ..... | 1.12 | 1.03 | 0.95 | 0.89 | 0.83 | ..... | ..... | ..... |
| 17 | 1.28 | 1.16 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 18 | 1.30 | 1.17 | 1.04 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 19 | 1.25 | 1.14 | 1.03 | 0.94 | ..... | ..... | ..... | ..... | ..... | ..... |
| 24 | ..... | 0.79 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 25 | 0.89 | 0.62 | 0.50 | 0.42 | 0.35 | ..... | ..... | ..... | ..... | ..... |
| 26 | ..... | 0.86 | 0.65 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 27 | 1.27 | 1.06 | 0.90 | 0.75 | ..... | ..... | ..... | ..... | ..... | ..... |
| 29 | ..... | ..... | 1.02 | 0.90 | 0.81 | ..... | ..... | ..... | ..... | ..... |
| 30 | 1.18 | 1.05 | 0.93 | 0.82 | 0.72 | 0.64 | 0.57 | ..... | ..... | ..... |
| 31 | 1.24 | 1.10 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Monthly means | 1.27 | 1.04 | 0.97 | 0.89 | 0.84 | 0.81 | 0.74 | ..... | ..... | ..... |
| Departure from 8-year normal | +0.05 | −0.05 | −0.03 | −0.02 | −0.02 | −0.02 | ..... | ..... | ..... | ..... |
| P. M. | | | | | | | | | | |
| July 2 | ..... | 1.27 | 1.22 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 26 | ..... | 0.88 | 0.80 | 0.72 | ..... | ..... | ..... | ..... | ..... | ..... |
| 27 | ..... | 1.11 | 0.98 | 0.86 | ..... | ..... | ..... | ..... | ..... | ..... |
| 30 | ..... | 1.05 | 0.96 | 0.86 | 0.81 | ..... | ..... | ..... | ..... | ..... |
| 31 | ..... | 1.09 | 1.04 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Monthly means | ..... | 1.08 | 1.00 | 0.81 | (0.81) | ..... | ..... | ..... | ..... | ..... |
| Departure from 8-year normal | ..... | −0.02 | +0.06 | −0.04 | −0.05 | ..... | ..... | ..... | ..... | ..... |

TABLE 1.—*Solar radiation intensities during July, 1917*—Continued.

**Lincoln, Nebr.**

| Date. | Sun's zenith distance. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.0° | 48.3° | 60.0° | 66.5° | 70.7° | 73.6° | 75.7° | 77.4° | 78.7° | 79.8° |
| | Air mass. | | | | | | | | | |
| | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 |
| A. M. | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* |
| July 2 | 1.42 | 1.34 | 1.27 | 1.19 | 1.11 | 1.01 | 0.91 | ..... | ..... | ..... |
| 3 | ..... | ..... | 1.12 | 1.03 | 0.94 | 0.87 | 0.79 | ..... | ..... | ..... |
| 6 | 1.39 | 1.16 | 1.02 | 0.92 | 0.85 | 0.79 | ..... | ..... | ..... | ..... |
| 9 | 1.36 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 10 | 1.34 | 1.27 | 1.15 | 1.01 | 0.83 | 0.78 | 0.70 | ..... | ..... | ..... |
| 11 | 1.45 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 12 | 1.35 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 13 | ..... | ..... | 1.10 | 1.01 | ..... | ..... | ..... | ..... | ..... | ..... |
| 16 | ..... | ..... | 1.22 | 1.13 | ..... | ..... | ..... | ..... | ..... | ..... |
| 17 | 1.39 | 1.23 | 1.10 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 18 | 1.43 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 19 | ..... | 1.24 | ..... | 1.05 | 0.99 | 0.90 | ..... | ..... | ..... | ..... |
| 20 | ..... | 1.18 | 1.07 | 0.97 | 0.87 | 0.80 | 0.73 | ..... | ..... | ..... |
| 23 | 1.28 | 1.20 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 24 | ..... | ..... | 1.00 | 0.88 | ..... | ..... | ..... | ..... | ..... | ..... |
| 25 | ..... | 0.91 | 0.87 | 0.81 | 0.75 | 0.68 | 0.60 | ..... | ..... | ..... |
| 27 | 1.32 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 28 | 1.36 | 1.27 | 1.15 | 1.06 | 0.97 | 0.91 | 0.84 | ..... | ..... | ..... |
| 30 | 1.38 | 1.30 | 1.21 | 1.10 | 1.02 | 0.96 | 0.87 | ..... | ..... | ..... |
| Monthly means | **1.37** | **1.21** | **1.11** | **1.01** | **0.93** | **0.86** | **0.78** | ..... | ..... | ..... |
| Departure from 3-year normal | **+0.03** | **+0.01** | **+0.01** | **−0.01** | **+0.01** | **+0.01** | **−0.02** | ..... | ..... | ..... |
| P. M. | | | | | | | | | | |
| July 2 | ..... | 1.31 | 1.21 | 1.12 | 1.05 | 0.98 | 0.89 | ..... | ..... | ..... |
| 3 | ..... | 1.32 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 6 | ..... | 1.29 | 1.18 | 1.10 | 1.04 | 0.98 | 0.92 | ..... | ..... | ..... |
| 9 | ..... | 1.25 | 1.16 | 1.09 | 1.02 | 0.95 | 0.89 | ..... | ..... | ..... |
| 17 | ..... | 1.26 | 1.16 | 1.03 | 0.96 | 0.90 | 0.81 | ..... | ..... | ..... |
| 18 | ..... | 1.20 | 1.06 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| 23 | ..... | 1.21 | 1.09 | 1.01 | 0.94 | 0.88 | 0.82 | ..... | ..... | ..... |
| 27 | ..... | 1.14 | 1.03 | 0.92 | 0.82 | 0.74 | ..... | ..... | ..... | ..... |
| 28 | ..... | 1.20 | 1.09 | 0.99 | 0.91 | 0.82 | 0.74 | ..... | ..... | ..... |
| 30 | ..... | 1.25 | 1.05 | 0.92 | 0.83 | 0.73 | 0.65 | ..... | ..... | ..... |
| Monthly means | ..... | **1.24** | **1.11** | **1.02** | **0.95** | **0.87** | **0.82** | ..... | ..... | ..... |
| Departure from 3-year normal | ..... | **+0.04** | **+0.02** | **+0.03** | **+0.04** | **+0.03** | **+0.05** | ..... | ..... | ..... |

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

| Washington, D. C. | | | Madison, Wis. | | | Lincoln, Nebr. | | |
|---|---|---|---|---|---|---|---|---|
| Dates. | 8 a. m. | 8 p. m. | Dates. | 8 a. m. | 8 p. m. | Dates. | 8 a. m. | 8 p. m. |
| 1917. | *mm.* | *mm.* | 1917. | *mm.* | *mm.* | 1917. | *mm.* | *mm.* |
| July 2 | 16.20 | 16.79 | July 2 | 9.47 | 9.47 | July 2 | 10.21 | 11.20 |
| 17 | 16.20 | 15.65 | 3 | 8.81 | 12.24 | 3 | 9.60 | 9.83 |
| 28 | 12.24 | 17.37 | 4 | 10.21 | 13.13 | 6 | 14.60 | 12.68 |
| 30 | 19.89 | 20.57 | 8 | 15.11 | 17.96 | 9 | 17.37 | 11.81 |
| 31 | 20.57 | 22.76 | 9 | 16.20 | 12.68 | 10 | 12.68 | 12.24 |
| ..... | ..... | ..... | 10 | 10.59 | 12.68 | 11 | 15.11 | 9.47 |
| ..... | ..... | ..... | 12 | 11.38 | 12.24 | 12 | 9.83 | 12.24 |
| ..... | ..... | ..... | 13 | 10.21 | 13.61 | 13 | 13.13 | 12.24 |
| ..... | ..... | ..... | 14 | 12.24 | 13.61 | 16 | 10.59 | 10.59 |
| ..... | ..... | ..... | 15 | 12.24 | 15.11 | 17 | 10.59 | 9.14 |
| ..... | ..... | ..... | 17 | 12.24 | 13.61 | 18 | 11.81 | 10.97 |
| ..... | ..... | ..... | 18 | 12.24 | 10.59 | 19 | 13.61 | 11.81 |
| ..... | ..... | ..... | 19 | 13.61 | 15.11 | 20 | 14.60 | 12.68 |
| ..... | ..... | ..... | 24 | 15.65 | 18.59 | 23 | 16.79 | 13.61 |
| ..... | ..... | ..... | 25 | 16.79 | 21.28 | 24 | 16.20 | 16.20 |
| ..... | ..... | ..... | 26 | 18.59 | 19.23 | 25 | 10.20 | 16.79 |
| ..... | ..... | ..... | 27 | 13.13 | 12.68 | 27 | 17.96 | 11.38 |
| ..... | ..... | ..... | 29 | 19.89 | 17.96 | 28 | 13.13 | 10.59 |
| ..... | ..... | ..... | 30 | 17.37 | 21.28 | 30 | 13.61 | 11.38 |
| ..... | ..... | ..... | 31 | 17.96 | 17.37 | ..... | ..... | ..... |

TABLE 3.—*Daily totals and departures of solar and sky radiation during July, 1917.*

[Gram-calories per square centimeter of horizontal surface.]

| Day of month. | Daily totals. | | Departures from normal. | | Excess or deficiency since first of month. | |
|---|---|---|---|---|---|---|
| | Washington. | Madison. | Washington. | Madison. | Washington. | Madison. |
| 1917. | *calories.* | *calories.* | *calories.* | *calories.* | *calories.* | *calories.* |
| July 1 | 594 | 607 | 71 | 60 | 71 | 60 |
| 2 | 628 | 764 | 105 | 217 | 176 | 277 |
| 3 | 300 | 342 | −222 | −204 | −46 | 73 |
| 4 | 416 | 562 | −105 | 16 | −151 | 89 |
| 5 | 398 | 404 | −122 | −141 | −273 | −52 |
| 6 | 589 | 222 | 70 | −322 | −203 | −374 |
| 7 | 466 | 537 | −51 | −6 | −254 | −380 |
| 8 | 160 | 595 | −356 | 54 | −610 | −326 |
| 9 | 321 | 691 | −194 | 151 | −804 | −175 |
| 10 | 416 | 657 | −98 | 119 | −902 | −56 |
| 11 | 380 | 217 | −133 | −319 | −1,035 | −375 |
| 12 | 548 | 641 | 37 | 107 | −998 | −268 |
| 13 | 529 | 611 | 19 | 79 | −979 | −189 |
| 14 | 391 | 626 | −118 | 96 | −1,097 | −93 |
| 15 | 299 | 624 | −209 | 96 | −1,306 | 3 |
| 16 | 504 | 394 | −2 | −131 | −1,308 | −128 |
| 17 | 570 | 581 | 65 | 59 | −1,243 | −69 |
| 18 | 246 | 628 | −258 | 109 | −1,501 | 40 |
| 19 | 347 | 596 | −155 | 80 | −1,656 | 120 |
| 20 | 364 | 544 | −137 | 31 | −1,793 | 151 |
| Decade departure | | | | | **−891** | **+207** |
| 21 | 483 | 462 | −17 | −48 | −1,810 | 103 |
| 22 | 208 | 271 | −291 | −236 | −2,101 | −133 |
| 23 | 345 | 493 | −152 | −11 | −2,253 | −144 |
| 24 | 462 | 558 | −34 | 57 | −2,287 | −87 |
| 25 | 176 | 490 | −319 | −8 | −2,606 | −95 |
| 26 | 388 | 552 | −106 | 57 | −2,712 | −38 |
| 27 | 478 | 631 | −15 | 139 | −2,727 | 101 |
| 28 | 649 | 581 | 158 | 92 | −2,569 | 193 |
| 29 | 421 | 632 | −69 | 146 | −2,638 | 339 |
| 30 | 576 | 614 | 87 | 131 | −2,551 | 470 |
| 31 | 600 | 609 | 112 | 129 | −2,439 | 599 |
| Decade departure | | | | | **−646** | **+448** |
| Excess or deficiency since first of year. | gr.-cal. | | | | −4,914 | +746 |
| | per cent | | | | −6.1 | +0.9 |

## SECTION II.—GENERAL METEOROLOGY.

### MEAN ANNUAL RAINFALL OF THE UNITED STATES WITH NOTES ON THE NEW CHART OF AVERAGE ANNUAL PRECIPITATION

from the "Atlas of American Agriculture" (Advance Sheet).

By ROBERT DECOURCY WARD, Professor of Climatology.

[Dated: Harvard University, Cambridge, Mass., June 29, 1917.]

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INTRODUCTION.

*Rainfall maps in general.*—There are difficulties in the study of the rainfall distribution over so large an area as that of the United States. Not only do the charted amounts of precipitation vary greatly in different sections, but there is still, and will be for years to come, some uncertainty as to just how much rain and snow actually fall. This is especially true of the western plateau and mountain country. Here, raingages are generally widely scattered, and are mostly at relatively low levels, so that but little can be definitely known regarding the precipitation on the mountains. These difficulties are by no means confined to the West. Even in thickly settled areas, raingage readings are known to be unsatisfactory. The local conditions of exposure, of altitude, of topography, have so marked an influence on the catch of the individual gage that the whole matter of actual rainfall distribution is much in doubt.

Rainfall maps for the United States are numerous. They differ considerably from one another. Some authorities have limited themselves fairly, or absolutely, rigidly to the observed readings of raingages. Others have based their maps on actual observations so far as these go, but have taken a further step. They have made use of all the known facts regarding topography, stream flow, wind direction, vegetation, and other conditions. These facts are taken into account in making reasonable inferences as to the amounts of precipitation over the higher mountain slopes and summits, and over unoccupied areas in general. Isohyetal lines are then drawn accordingly. There has thus been a good deal of divergence in the views of those to whom we owe our rainfall maps (1).

What may be termed the more strictly meteorological group has, in general, taken the position that such charts should show only such amounts of precipitation as have been actually measured. They have held that inferences regarding precipitation over areas where no records are available, necessarily largely reflect only the individual opinion of the author and lose greatly in value on that account. They maintain that, when inferred isohyetal lines are drawn over regions where there are but few stations, that fact should be very clearly indicated, a distinction being made between observed and inferred conditions. In the case of mountains whose rainfall is not definitely known, there is no reason why the area should not be left blank on the map. Or, if desired, the slopes for which observations are lacking may be inclosed by an isohyetal line whose position is definitely established, and the words "probably over — inches, or millimeters" may be entered within this line. On the other hand, the second group, which is largely composed of geographers and of those who have broad geographic conditions in mind, takes the view that the relief and all other known surface features of the country should be recognized and utilized in inferring the positions of the isohyetal lines, and that many serious errors in locating these lines, such as drawing a line across a hilltop when it should obviously go around the base, may be avoided if a contour map is used. The extent to which the topography of any region should be taken into account obviously depends on the scale of the map. The smaller the scale the fewer the details which may be shown (1).

The purpose of the present paper is to make clear the essential facts regarding the rainfall of the United States, by eliminating all unnecessary details and avoiding confusion. This discussion has, therefore, only an academic interest. The present point of view is broadly geographical rather than strictly meteorological. Hence a rainfall map which attempts, on a reasonably sound basis of topography, water supply, and vegetation, to show the inferred amounts of precipitation over areas where gage readings are lacking, is more satisfactory than one which is based solely upon actually recorded amounts of rainfall. In any study of rainfall charts it must be remembered that the transition from one color or one kind of shading to another, which stands out so strikingly on the maps, gives an erroneous impression of a suddenness of change in the amount of rainfall on the two sides of that line. The increase or the decrease in rainfall from that indicated by one isohyetal line, or by one color or shading, to that shown by the next is gradual.

In detailed studies of rainfall, as in its relation to crops, or irrigation, or water power, it is usually necessary to use maps which show the amounts of precipitation for every 10 inches, 5 inches, or even 1 inch. For more general purposes, as in a review of the larger facts of rainfall, it is simpler and generally sufficient if the distribution of certain more or less critical rainfall amounts is alone considered. This latter scheme is, for example, well adapted for use in constructing wall maps of mean annual rainfall, where the larger facts must be presented in the clearest possible way. From the point of view of man and of his relation to the mean annual rainfall it has become more or less conventional to adopt certain "critical" grades of rainfall. Such critical rainfall amounts are below 5 inches (1); 5 to 10 inches (2); 10 to 20 inches (3); 20 to 40 inches (4); and over 40 inches (5). Districts of very heavy rainfalls, of 80 inches and over (5), may be included as a separate group. Where the rainfall is less than 5 inches a year there are true deserts. Where 5 to 10 inches fall the country is arid. Agriculture requires irrigation. The available water supply is extremely limited. Only a small portion

of these areas can ever be useful to man. The districts with 10 to 20 inches are generally called semiarid. Roughly, they include "dry-farming" areas, although, as shown by L. J. Briggs and J. O. Belz (2), these rainfall limits are only approximate in the United States. Many factors besides the mean annual rainfall control agricultural operations, e. g., the monthly distribution of the rain; the amount of evaporation; the temperature; the methods of cultivation; the soil, etc. Dry-farming is carried on, more or less successfully, over increasing portions of this semiarid area in the United States, and there is also a considerable use of irrigation over other smaller parts of it. The development of these areas has been rapid, and there is still possibility of great future development. Rainfalls of 20 to 40 inches are sufficient for all ordinary agricultural or water-supply purposes. Above 40 inches, and up to (say) 80 inches, the amount is abundant, and above 80 inches it may be described as superabundant. The use of some such grades of rainfall simplifies the description of ordinary precipitation charts and helps greatly in memorizing them.

### THE NEW MEAN ANNUAL PRECIPITATION CHART OF THE UNITED STATES.

What will, for many years to come, be the standard chart of mean annual precipitation for the United States has recently been published (this REVIEW Chart XLV—76). It is an "advance sheet" (January, 1917) from the forthcoming Atlas of American Agriculture. It embodies the best and the latest information which is now available. It recognizes the absolutely essential importance of using only records covering a uniform period or reduced to a uniform period.[1] In the location of the isohyetal lines it takes reasonable account of topography and of other conditions which indicate, or which control, the amount of precipitation. Printed in eight shades of blue (under 10 inches; 10 to 15 inches; 15 to 20 inches; 20 to 30 inches; 30 to 40 inches; 40 to 50 inches; 50 to 60 inches; over 60 inches), with isohyetal lines drawn for every 5 inches, on a base map 24 by 16 inches showing the topography clearly and in ample detail, with the names of all the more important mountain ranges and individual mountains given, the new map is not only in itself interesting and pleasing cartographically, but it brings out many details of rainfall distribution which make its close study well worth while. The records of about 1,600 stations for the 20-year period 1895–1914 have been used, together with 2,000 additional records from 5 to 19 years in length. The latter series, it is most satisfactory to note, have been "uniformly adjusted to the same period," i. e., they have been reduced to the same uniform period of 20 years. This reduction, which is inevitably a very laborious piece of work, the large number of stations employed and the use of records through the year 1914 combined, make the new chart by all means the most accurate one which is available for the United States. Careful distinction is made, by symbols, between the different classes of stations. A small inset map (6×4 inches) shows the percentage of annual precipitation occurring between April 1 and September 30 (five shades of color), and was compiled from the records of about 1,600 stations, 1895–1914. An inset diagram shows the period of the year within which 50 per cent of the annual precipitation occurs in 12 districts. The text which is to accompany this new map has not yet been published. The discussion which follows therefore is not based on the official descriptive text which will doubtless soon be available for distribution.

[1] The principles recognized and followed in preparing the accompanying new annual rainfall chart are set forth by its authors in the paper "The preparation of precipitation charts," by Wm. G. Reed & J. B. Kincer, MONTHLY WEATHER REVIEW, May, 1917, 45:233–235.

### CLIMATIC PROVINCES OF THE UNITED STATES.

The rainfall of the United States is best considered, not by taking the country as a whole, but by dealing with certain large subdivisions individually. The subdivisions here used are those suggested by the present writer in 1915, and shown in figure 1 (3).

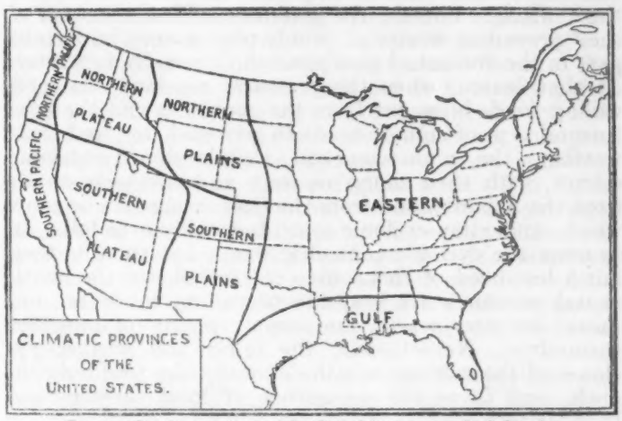


FIG. 1.—Climatic provinces of the United States. (R. DeC. Ward.)

### RAINFALL OF THE UNITED STATES.

#### *Eastern and Gulf Provinces.*

*Source of moisture.*—The isohyetal lines over the eastern and especially the southeastern United States show a general parallelism with the trend of the Atlantic and Gulf of Mexico coasts, which is highly significant. They "head up" to these two bodies of water. They spread out from the Gulf of Mexico toward the interior. This fact, together with the distinct decrease in rainfall with latitude northward from the Gulf, and the decrease with longitude westward from the Atlantic, clearly indicates that these two sources of water vapor are absolutely essential in supplying the precipitation over this section of the country. Of these two bodies of water, the Gulf of Mexico is the more important. From that source comes, directly or indirectly, the bulk of the rain which falls from the Rocky Mountains eastward and southward. From St. Paul, Minn., to New Orleans, La., the mean annual rainfall [precipitation] increases by nearly 30 inches. The influence of the Atlantic Ocean is clearly seen along the eastern seaboard, extending inland to the Appalachians, especially over the northern sections of the coast. It is probable that the bulk of the direct supply from the Atlantic does not extend inland to any considerable extent beyond the Appalachians. From Eastport, Me., to St. Paul, Minn., the decrease in mean annual rainfall is about 15 inches. The Great Lakes are a subordinate and *relatively* unimportant source of rainfall.

The importance of the Gulf of Mexico and of the Atlantic Ocean in supplying the moisture which, owing to the western mountain barriers, is prevented from coming far inland from the Pacific, can not be overemphasized. Taken as a whole, a remarkable combination of favorable conditions exists for producing abundant and well-distributed rainfall over the eastern United States. First, the warm waters of the Gulf of Mexico—

occupying latitudes which, with a different distribution of land areas, would be an American Sahara—and the Atlantic Ocean, kept at a relatively high temperature along a considerable extent of the coast by the warm Gulf stream, are near-by sources of a plentiful water-vapor supply. Second, the prevailing winds during the most critical season of the year (summer) blow—with an almost monsoon like persistence—from the warm waters of the Gulf of Mexico, at high temperatures and well laden with water vapor, far into the interior of the continent. Third, the topography of the eastern half of the country offers no serious obstacle anywhere to the free flow of these winds. Fourth, the ordinary cyclonic storms of the "prevailing westerly" winds play a very important part in the control of precipitation, especially in winter. At that season, when the pressures are high, the prevailing winds blow out from the continent and the continental type of climate tends to give cold, dry, and clear weather, the numerous and well-developed cyclonic storms, with their damp easterly and southerly winds from the Atlantic, and from the Gulf, bring rain or snow which, under non-cyclonic controls, would never fall. In summer the cyclonic control is weak; but there is then much less need of this source of rainfall, for the continental pressures are low, the prevailing winds are onshore, are very warm, and supply plenty of moisture themselves. Nevertheless, the fewer and weaker cyclones of the warmer months intensify the southerly indraft, and favor the occurrence of local showers and thunderstorms.

*No mountain barriers.*—The rain-shadow effect of the western mountains would prove a very serious climatic handicap to the region lying to the east of the Rocky Mountains if it were not for this remarkable combination of conditions. In eastern Asia, in latitudes 30° to 40° N., there is a district climatically similar in many respects to the eastern United States in the same latitudes. Yet in Asia, owing to an absence of some of the favorable controls which are so striking in North America, the area with precipitation over 40 inches is greatly restricted. In western Europe, on the other hand, there are no high western mountains. Hence there are no such marked rain-shadow effects as in the United States. Hence, also, there is no similar need for a new moisture supply for the interior sections such as exists in the United States. The Mediterranean Sea seems analogous to the Gulf of Mexico, but the influence of the former is fairly well shut out from the interior by the mountain barrier of southern Europe. It is very fortunate for the United States that there is no transverse mountain barrier, like the Alps, stretching across the Mississippi Valley. In Europe teh Alpine barrier is not a climatic handicap, because the moisture supply from the Mediterranean is not essential to the countries lying to the north.

*General distribution.*—The extraordinarily favorable rainfall conditions which prevail over the eastern United States have inevitably attracted the attention of almost all writers on the climatology of North America. Prof. W. M. Davis has stated the case none too emphatically when he says: "Although droughts sometimes affect considerable districts, and floods occasionally devastate the larger valleys, yet the world hardly contains so large an area as this, so well adapted to civilized occupation." (4)

Everywhere over this great area the rainfall is over 20 inches; about one-half the area receives more than 40 inches; no inconsiderable portion has more than 50 inches; in restricted localities the amounts exceed 60 inches. The rainfall is greatest (in general, 50 to 60 inches) over the Gulf States, with the exception of Texas, and along most of the immediate seaboard of the Carolinas and Georgia. It decreases from these amounts, and from 40 to 45 inches over most of the northern and central Atlantic coast; to 30 to 40 inches over the prairies; and to 20 inches at about the 100th meridian. In the West the isohyetal lines trend nearly north–south. The heavier rainfalls, excluding those due to topographic controls, are thus found near the bodies of water which supply the moisture. From Florida, along the eastern and northern Gulf coasts to the southwestern corner of Louisiana, the amounts vary between 50 and 60 inches. Most of Louisiana, Mississippi, and Alabama, and a good deal of southern Arkansas, have over 50 inches. Along the Texas coast there is a very rapid decrease from 50 inches in the northeast to 20 to 25 inches in the extreme south, the isohyetal lines trending very nearly north and south. This Texas section is not nearly as favorably located with regard to rainfall as is the rest of the Gulf coast, both in the matter of its exposure to the prevailing damp winds blowing across the Gulf and in its relation to cyclonic storms. Along the Atlantic seaboard, the amounts decrease somewhat with increasing latitude, from 55 to 60 inches in extreme southeastern Florida to 40 to 45 inches in Maine.

*Appalachians.*—The influence of the Appalachian Mountains is indicated in the irregularity of many of the isohyetal lines, and in the occurrence of certain local areas of heavier or lighter precipitation. As a whole, however, since the mountains are not very high, and since their trend is approximately parallel with that of many of the rain-bearing winds and with the tracks of numerous cyclones, it is not to be expected that there should be any very marked differences in rainfall on the opposite slopes. The most marked topographic control over rainfall in the Appalachians is in a small area along the southern and eastern slopes of the mountains of southwestern North Carolina, northwestern South Carolina, and northern Georgia. In this elongated area the rainfall amounts increase from 50 and 55 inches over the lower slopes to 60 inches at greater elevations, reaching 80 inches at a maximum in one small area in the mountains of the southwestern corner of North Carolina. This is the maximum mean annual rainfall anywhere east of the Sierra Nevada–Cascade divide. A combination of topography and of exposure to rain-bearing winds doubtless explains this interesting peculiarity. Far away to the north, the White Mountains of New Hampshire (Mt. Washington) stand out as a small district of heavier precipitation (50 to 60+ inches), and in New York State the position of the Adirondacks is clearly indicated by the isohyetal lines of 45 and 50 inches. The higher parts of the Cumberland Plateau in Tennessee, have over 55 inches, and there are other less important areas with somewhat increased precipitation, e. g., the mountains of West Virginia. Noticeable, also, are the effects of the topography in causing somewhat diminished rainfall. The Hudson–Lake Champlain depression is clearly marked, with less than 30 inches in the north. The inner longitudinal valleys of Virginia and West Virginia stand out sharply with their 40 and even 35-inch isohyetal lines, a rainfall 5 to 10 inches or more below that of the surrounding mountain country. The plentiful rainfall over the Appalachian area as a whole furnishes abundant water power in numerous well-filled rivers, and thus becomes an important factor in the industrial development of the eastern States. The only other striking topographic controls over rainfall in the eastern United States are seen in the deflection of the 50-inch line over the Ouachita Mountains of central Arkansas and in the local

increase of rainfall from 40 to 50 inches over the Boston Mountains in the northwestern part of the same State.

*Great Lakes.*—The chart does not indicate any very striking influence of the Great Lakes on the mean annual precipitation in their immediate vicinity. This fact was pointed out many years ago by Blodget. In 1899, Prof. A. J. Henry wrote: "The Lakes themselves, with the possible exception of Lake Superior, do not seem to have a very marked influence on the precipitation of moisture on adjacent land areas" (5). The lee shores of the Lakes in several cases show a somewhat heavier annual rainfall, but relatively the excess is a rather small amount, generally not over 5 inches. The Lake effect is probably greatest in the case of Lake Superior. Local topography is here, as always, an important factor in determining the amount of rainfall. There is a rather significant widening toward the Lakes, of the belt between the 30 and 35-inch isohyetal lines and, to a somewhat less marked degree, of that between the 35 and 40-inch lines. This fact, together with the general trend of the lines in the Lakes region, indicate that the Lakes influence is present although it is not striking. It should be borne in mind that the rainy winds are to a considerable extent from easterly directions, and for that reason the lack of any very decided influence of the "prevailing westerlies" is not surprising. It is to be expected that in winter, when the westerly winds blow across the open water of the Lakes, the snow will be heavier on the lee sides. It may be observed that the Great Lakes are not bountifully supplied by many large rivers. Hence they are very dependent for their water supply upon local rain and snowfall. An interesting point regarding the Great Lakes was brought out by Blodget (6), when he wrote that they "could not exist if extreme continental features of climate were ever fairly developed there." In other words, the Lakes occupy a district which naturally has a well-marked continental climate and unless the extremely favorable conditions for rainfall which have been explained above, were present there would be a deficiency of rainfall here. These conditions result in a modification of the continental characteristic of deficient or light rainfall; the Great Lakes basins are well filled and the Lakes, in their turn, modify the local climates.

*Population.*—The bulk of the population of the United States is found in this eastern section (embracing the Eastern and Gulf Provinces), where the mean annual rainfall ranges between 20 and 50 inches. Here sufficient moisture favors successful agriculture, with annual summer crops raised by ordinary farming methods. Here the rainfall is favorable so that the agricultural provinces are based largely on temperature and therefore in general follow the latitude lines; latitude and soil being the principal crop controls (7). It is the sufficiency of the rainfall, combined with its favorable distribution through the year, that is of such inestimable advantage to agricultural prosperity. The generally abundant spring and early summer showers; the prevailingly high summer temperatures; and the plentiful supply of atmospheric humidity; combine to produce an almost semitropical type of summer climate very favorable, in the South, for sugar cane and for cotton and, farther North, for wheat, corn, oats, and other cereals. It has been well said that "there is no great area so far in the interior which presents a similar result"(6).

### *Rainfall of the Great Plains.*

*Distribution.*—The general east–west and northeast–southwest trend of the isohyetal lines over the Southern and Eastern States becomes a roughly north–south trend over and somewhat to the east of the Great Plains, and continues to be the general characteristic all the way to the Pacific with, of course, many local irregularities due to topographic controls. The isohyetal lines may be thought of as swinging on a pivot located over the western Gulf States, their eastern free ends traveling north, northwest, and west until they reach an approximately north–south position. The 20-inch line, because of its critical controls over vegetation, is often taken as the eastern boundary of the Great Plains. It lies in a general way along the 100th meridian, but is east of it in the Dakotas, and west of it in the remaining States to the south. Hence, along the 100th meridian, the rainfall is between 15 and 20 inches in the north, and about 25 inches in Oklahoma and most of Texas. This difference between north and south naturally points to the Gulf of Mexico as the source of the rainfall. There is, thus, over the Plains as a whole, no change of rainfall with latitude; no decrease, as there is farther east; no increase, as there is farther west. The Rocky Mountain divide roughly separates these two contrasted relations of rainfall and latitude. Over the Plains, owing to the increasing distance from the chief source of moisture, the rainfall as a whole decreases toward the west, in spite of the fact that the altitude increases, falling to 10–15 inches over much of eastern Montana, Wyoming, and Colorado.

*Orographic controls.*—For the sake of simplicity and convenience the "Plains Province" may be limited on the west by the Continental Divide (see fig. 1). In such a scheme of subdivision, much of the so-called Plains Province includes a highly varied mountain topography, with mountain climates, and many marked cases of topographic controls over rainfall. At a first glance the rainfall map gives the impression of complexity and confusion, but a more careful examination of its details leads to the following simple statement. The more marked, i. e., the higher, topographic features are clearly local centers of heavier precipitation, but the amounts are in no case excessive (20 to 25+inches) in any degree. Several mountain groups are clearly indicated by their heavier rainfalls. Such are the Black Hills of South Dakota; the Lewis Range and the Little Belt Mountains of Montana; the Absaroka and Wind River Ranges and the Big Horn Mountains of Wyoming; the Front, Park, and Sawatch Ranges, and Pikes Peak in Colorado; the Sangre de Cristo Mountains of Colorado and New Mexico. The Black Hills, so named because of their dark forests which result from the heavier rainfall, are a center of lumbering in the midst of a surrounding treeless country of cattle or sheep ranges. Elsewhere, also, the increased precipitation of the greater elevations makes possible forest growth. The "parks" of Colorado, for example, have sufficient precipitation to support a growth of pines which add greatly to the natural beauty of these intermont basins. A few districts which are topographically unfavorably situated, have less than 10 inches of rainfall. Such are the Big Horn and Green River districts of Wyoming; and a smaller area between the Sangre de Cristo and San Juan Mountains in Colorado.

*Relative dryness.*—Too far from the Atlantic and the Gulf of Mexico on the one side to be able to receive an abundant supply of moisture from those sources, and too far and too well shut off from the Pacific on the other to be able to draw upon that source, the Plains must inevitably be relatively dry. Storms cross them, it is true, especially in the north and in winter, but precipitation can not be heavy when the inflowing winds do not carry much moisture. The somewhat more

abundant rainfall of the loftier mountains is an important source of supply for the rivers whose waters are used for irrigating the lower country to the eastward. An annual rainfall of 20 inches, combined with high summer temperatures, marks about the limit below which permanently successful agriculture on a large scale and without irrigation, as practiced over the great farming lands farther east, is not possible. To the west of the 20-inch isohyetal line, therefore, over the Plains, there is a vast region where agriculture of the type characteristic of the rainier east is as a whole no longer found (except on the northern Pacific coast); where water, not land, is the measure of success. Over all this great western area the agricultural provinces are determined by altitude and rainfall. They therefore extend roughly north and south, as do the mountain systems; and not east and west under the control of temperature, as they do in the east (7). Dry farming, grazing, irrigation are man's three methods of making use of the land. Dry farming, where the rainfall is most abundant; stock raising, where there is not enough moisture even for dry farming; irrigation, over the limited areas where water is available. Once the home of immense herds of bison which pastured on the natural grasses; then browsed over by millions of cattle; later, in the days of the "boom," the scene of unhappy and disastrous attempts to use them for large-scale agricultural operations of the eastern type; the natural limitations of the Great Plains have come to be fully recognized. They were never fitted to be a region of vast farms for raising crops by methods which take no account of the special climatic and soil limitation (8). They could not continue to support vast herds of cattle which exhausted the natural pasturage. They are available, here for dry farming; there for local irrigation from streams or wells, with small individual farms and cattle ranches, each farm having its own cultivated patch of cereals, and vegetables, and fodder for the cattle; and elsewhere, again, for grazing.

It has been pointed out by Henry (9) that, while no hard and fast rule can be laid down, the line of 15 inches of rainfall per crop-growing season very broadly defines the area which is devoted to the cultivation of cereals in the United States. Yet the very remarkable crops harvested in the Red River Valley are produced with a less amount, and in the dry-farming wheat region about Spokane, Wash., the rainfall in April–June averages 4.5 inches, which is about that of a single month in the Mississippi Valley wheat country. In discussing the relation of spring-sown wheat yield to rainfall on the Great Plains, Messrs. Briggs and Belz (2) conclude that when the rainfall for April–July, inclusive, is less than 8 inches, the yield barely suffices to cover the expense of producing the crop. It is significant that the heavier precipitation of the eastern United States, combined with favorable conditions of temperature and soil, produced a great natural forest cover which the early settlers were obliged to clear away. This was a slow and laborious task, and greatly delayed the progress of white settlement. In the West, on the other hand, over the treeless areas of the Great Plains, for example, there was no such obstacle. Vast stretches of the West were available for rapid occupation, for grazing, or for agriculture. The difficulty here is the impossibility of supporting a large population, owing to the deficient rainfall.

### *The Plateau Province.*

Over the western Plateau Province, with its varying topographic features, its rugged slopes, and its sparse population, the rainfall is still but imperfectly known. This is distinctly a rain-shadow area, of generally deficient precipitation. It is desert, arid or semiarid, except when the higher mountains or plateaus provoke a more abundant rainfall, specially in the north where the mountain barrier is less effective and the storms are more numerous. The moisture which, if it were not for the western mountain barriers it would receive from the Pacific, in great part falls as rain or snow on the windward slopes of these mountains, on the narrow Pacific slope. Even the most superficial comparison of the topographic and the rainfall maps of the Plateau Province shows at once a remarkably close correspondence between them. In many respects the lower valleys and plateaus of this region are comparable, as pointed out by Voeĭkov, with the Aral–Caspian lowland. The most extreme deserts of the Old World are, however, more absolutely barren than the North American deserts.

*Northern division.*—It is convenient to consider the Plateau Province in two divisions, the northern and the southern (see fig. 1). The most striking feature on the precipitation map is the increased rainfall over the dominant mountain groups of Idaho (Bitter Root, Clearwater, and Salmon River Mountains) and of eastern Oregon (Blue Mountains). Annual amounts of 30 and 35 inches are shown over the upper slopes, with the isohyetal line of 40 inches inclosing a portion of the northern Bitter Root Range. These are the largest amounts (40 inches) shown anywhere in the Rocky Mountains area. Over the districts of least elevation, the Snake River Plains in southwestern Idaho, the great plains of southeastern and central Oregon and central Washington, rainfalls of less than 10 inches occur. Lying between the somewhat more abundant rainfall on the mountains and the too-great aridity of the districts with less than 10 inches, a fair portion of eastern Oregon and Washington, and of southern Idaho, has 10 to 20 inches. In certain of these districts dry farming has been carried on with a considerable degree of success, especially in the newly developed and fertile agricultural region of eastern Washington. Messrs. L. J. Briggs and J. O. Belz (2) have concluded that, with the evaporation which occurs in the Great Basin, a mean annual rainfall of 13 inches is about the minimum for profitable dry farming. In the basin of the Columbia River, in southern Washington and northern Oregon, wheat is successfully grown by summer-fallowing methods, with a mean annual rainfall of 10 inches, and the minimum for any profit at all seems to be about 8.50 inches. As these authors point out, there is probably no other part of these States where dry farming is practiced with so small a rainfall as this.

Land with too little rainfall even for dry farming, and which can not be irrigated, is to a considerable extent used for grazing, and irrigation has brought great prosperity to a number of communities which have become famous for their fruit crops, e. g., the Yakima Valley, in Washington. A railroad trip of great interest may be taken from the famous dry-farming wheat country around Spokane; southward on the treeless lava plateau; across the Columbia River, and then westward and northwestward up the valley of the Yakima River in the lee of the Cascade Mountains. Here man has turned the "desert" into one continuous garden. Here the wonderful orchards of apple, peach, and pear trees, the fields of hops and of alfalfa, and the vineyards reaching for miles and miles in every direction, make the traveler realize that the glowing accounts which have been given of this region are not greatly exaggerated. Upon the summits and upper slopes of the Cascades

there is a rainfall 10 or 15 times as great as that in the valleys at the eastern base—a rainfall resulting from the presence of the mountains across the path of the rain-bringing westerly winds. It is this water which has been collected for the use of man in the Yakima irrigation projects. The interest of the climatologist in this Yakima country is not so much in the number of carloads of fruit which are sent out, or in the size of the apples and pears and peaches, but rather in the relation of the dry, leeward, rain-shadow valleys to the well-watered mountain summits, and in the curious overlapping of the forests from the rainy western slopes into the higher portions of the valleys on the eastern slopes.

The Rocky Mountains as a whole, it should be noted, are not nearly as important controls of precipitation as might at first be expected. They are, in general, so far from the Pacific that their rainfall is not heavy. They are, furthermore, to leeward of the very considerable ranges of the Sierra Nevada and the Cascades. The rain-shadow effect of the Cascades is strikingly shown on the rainfall map in the contrast between the rainy western and the dry eastern slopes in Washington and Oregon.

*Southern division.*—The southern division of the Plateau Province is distinctly drier than the northern. With the exception of some local areas in the mountains the rainfall is less than 20 inches, mostly below 10 inches; over no insignificant portion it is even below 5 inches. Well removed from the most frequented track of cyclonic storms; in the lee of the great Sierra Nevada; shut off from the free access of rain-bearing winds; it is no wonder that this great province should be arid. This was all known, not many years ago, as the "Great American Desert." It is a region of interior drainage; of peculiar topographic forms dependent on the climate; and of Great Salt Lake, the feeble relic of a great ancestor, Lake Bonneville. The real "American Desert" lies in southeastern California, the southwestern angle of Arizona and western Nevada. If the continent were broader, there would be a much larger desert in these latitudes. The mean annual rainfall is only 5 inches. Death Valley is here, with its famous borax deposits and its intense summer heat. The Salton Sea is here—an anomaly in a true desert—originally supplied through the Colorado River by water which fell as rain or snow on the slopes of the Rocky Mountains far to the east; evaporating rapidly under the clear skies and high temperatures. The Black Rock desert; the "sinks" and the soda deposits of western Nevada are here.

Surrounding the "desert," with its hopelessly deficient rainfall, comes a considerably larger area with 5 to 10 inches—also arid and impossible for agriculture and for settlement without irrigation. This includes most of Nevada, western Utah, a strip across western Arizona, and other areas of relatively moderate elevation in northern Arizona, New Mexico, eastern Utah, and southwestern Wyoming. Over the higher mountain slopes and plateaus the amounts exceed 20 inches, locally; as across the central portion of the Arizona plateau, on the Wasatch and Uinta Mountains of Utah, the Absaroka, Wind River and other ranges of northwestern Wyoming (over 25 inches on the Absaroka Range), and the San Juan (over 30 inches) and other mountains of western Colorado. Intermediate rainfalls, from 10 through 15 to 20 inches are found distributed, in close agreement with the topography, over the intermediate altitudes. A topographic map is here a good rainfall map, and also a good vegetation map. For, while the lower-lying portions of this whole region are dry and barren, the increased precipitation over the more elevated plateaus and on the mountains, supports grass and often forests. Arizona, which rises more or less like a flight of steps from the southwestern corner, shows this relation very clearly. From a mean rainfall of less than 5 inches in its southwest, the amounts gradually increase to over 20 inches. The so-called "islands"—much more appropriately termed "lakes"—of heavier precipitation on the mountains are economically of great importance. They supply the water, chiefly melted snow, which is used for irrigating the arid lowlands. Phoenix, Ariz., for example, receives on the average less than 8 inches of rainfall annually. Over the watershed behind the Roosevelt Dam perhaps twice as much rain falls. This extra supply, resulting from the presence of the mountains, when carefully collected, stored and distributed, makes the glory of the Salt River Valley of which Arizona is so justly proud.

Wherever, throughout this province, the streams, supplied by the melting snows of the higher mountains, afford sufficient water for irrigation, bountiful crops await the farmer. But the water supply is limited, and many of the far too optimistic hopes for the future of the region have already been disappointed. Only where there is mineral wealth, in the form of precious metals or of salts, is there any value in land which has insufficient rainfall for farming and which can not be irrigated. The most valuable portions of the Plateau Province are those with 10 to 20 inches of rainfall.

*Rainfall of the Pacific coast.*

Rainfall and topography are also very closely related on the Pacific slope. The heaviest rainfalls in the United States (over 120 inches) occur on the Olympic Mountains of northwestern Washington. These are also among the heavy rainfalls of the world. More than 100 inches are indicated on the map for two small localities on the northern Coast Range of Washington and Oregon. Elsewhere the largest amounts are 80 inches. These are shown over the higher slopes and summits of the Cascade Range; over a small portion of the northern Sierra Nevada, and on the Coast Range as far south as northern California.

To the south, the rainfalls on the mountains decrease rapidly; although, as compared with the lowlands, they remain relatively very heavy. The 50-inch line on the Sierra Nevada does not extend south beyond the latitude of San Francisco; the 30-inch line reaches a little beyond the latitude of Fresno. The mountains of southern California are clearly shown on the map by their rainfalls of over 25 inches. Many streams, deep and swiftly flowing, rush down the slopes of these Pacific coast mountains, supplying water power, vast and never failing. The name of the Cascades at once suggests heavy precipitation. Here, in the future, when lumbering has ceased to be the chief industry, the varied manufacturing and industrial enterprises of a more complex and more thickly settled community will be developed by means of this water power, one of the most important assets of the Pacific slope.

Beautiful climatic cross sections, contrasting the rainy windward and the dry leeward sides, may be obtained when crossing either the Cascades or the Sierra Nevada by train. The contrast between the treeless lower lands east of the Cascades in Washington, and the densely forested western slopes is wonderfully impressive. In traveling by train from The Dalles of the Columbia River down the river to Portland, Oreg., the change in the character of the vegetation is an excellent "car-window" observation of the increase of rainfall, which just about

trebles between The Dalles and Portland (15 to 45 inches). The gorge of the Columbia River, it may be noted, is distinctly indicated by the isohyetal lines on the rainfall map. Again, in crossing the Sierra Nevada Mountains on the Central (Southern) Pacific Railroad, going east from San Francisco, the traveler can not fail to notice that the green slopes and forests of the Pacific side are rapidly replaced by the sagebrush and allied forms of vegetation on the east. From a precipitation of about 50 inches the descent takes place with remarkable suddenness into the Nevada desert, with its alkali flats, its dust and its less than 10 inches of rainfall. Railroads crossing these mountains are not infrequently subjected to heavy expenses on account of washouts resulting from the heavy rainfalls. Occasionally local landslides, caused by excessive downpours, add to the difficulties.

*Cause of heavy rain.*—The heavy rainfalls of the northern Pacific coast are similar in origin to those of the coasts of Scotland, of Norway, of Chile. The close proximity of the Pacific Ocean, from which the prevailing winds blow; the frequency, especially in winter, of cyclonic storms whose in-flowing winds, from several quarters, are well charged with moisture; the mountain barriers in the path of the onshore winds—these are the dominant controls. In winter, the land, especially the high land, is usually colder than the ocean and hence the onshore winds readily become damp and rainy. This condition combines with the greater storminess of the winter months to produce the Pacific type of rainfall, with its well-marked winter maximum. Even if there were no high mountains over the northern Pacific coast, the rainfall would doubtless still be ample for agricultural needs. The storm control is not dependent on topography. The southern portion of the Pacific coast is drier for several reasons. It is beyond the reach of most of the rain-bringing storms which pass across the northern sections. The lands, and even the mountain slopes, are warmer for much of the year, especially in summer, than the ocean, and the onshore winds therefore become drier and warmer. The prevailing winds also have a considerable northerly component, and are, for that reason, warming and hence drying winds.

In low latitudes within the easterly trade-wind belts, mountains on the western border of a continent, as, e. g. the Cordillera of South America, obviously have no rain-shadow effect on the interior. In the belt of "prevailing westerly" winds, *per contra*, a western mountain barrier, especially a double western mountain barrier, must necessarily become a marked rainfall divide, as in the United States. In Europe, with its more open western borders, there is no very marked rain-shadow effect. Scandinavia alone, with its drier interior (eastern) districts, presents a weak analogy with the United States.

*Southern California.*—The smallest rainfalls on the Pacific slope (excluding southeastern California) are those of the San Joaquin Valley (under 10 inches). This is clearly a topographic, rain-shadow effect. Going northward up the Valley of California, the rainfall gradually increases. Over most of the lower portions of the Sacramento Valley it is between 15 and 20 inches. The surrounding slopes all show heavier rainfalls, and the amounts increase rapidly at the northern end of the Sacramento Valley as the altitudes increase. San Diego, on the extreme southern coast, has about 10 inches. The increase, with latitude up to 100 inches on the coast of Washington, is just the opposite condition to that which is found on the Atlantic coast, where there is a decrease from Florida to Maine. The Willamette Valley of Oregon has less rainfall than the mountain ranges on both sides, but is abundantly watered (40 to 50 inches). In the extreme north and the extreme south of the intermontane lowlands of western Washington and Oregon there are small areas, distinctly topographically controlled, of less than 30 inches. In the Rogue River Valley, in southern Oregon, some of the fruit growers irrigate with a rainfall of about 30 inches.

Irrigation is absolutely essential over large sections of southern California. Of vast importance in the economic value of the southern counties of California is the very heavy winter snowfall on the Sierras. This supplies many streams that flow out over the lowlands and is the source of abundant water for power, for irrigation, and for city and household use. The Sierra Nevada Mountains well deserve their name. To them California owes much, if not most of her present propserity and of her promise for future growth and development. The many feet of winter snowfall which accumulate on these upper slopes mean millions upon millions of dollars each year to the farmers and fruit growers of southern California. Were all this precipitation to fall as *rain*, every Winter would witness devastating floods, and every Summer would wither and destroy the crops. On the western slopes of these mountains are found the "Big Trees." North of San Francisco, on the western slope of the Coast Range, are found the famous redwoods; and the "Oregon pine," from farther north, is known the world over because of its usefulness for ships' masts and spars. The amount of rain and snowfall, it should be noted, does not increase at a uniform rate all the way up the western slopes to the summits of the highest mountains. In his careful hydrographic work in connection with the Los Angeles aqueduct, C. H. Lee (**10**) has found that—

> precipitation on the west slope of the Sierra between the Yuba and Tuolumne Rivers increases at a variable rate, which, expressed as an average, is 0.85 inch per hundred-foot rise from the floor of the Great Valley to the 5,000-foot contour. Above the 5,000-foot contour it decreases approximately at the rate of 0.40 inch per 100-foot rise to the crest of the Sierra.

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## SEA BREEZE ON EASTERN LONG ISLAND.

By ERNEST S. CLOWES.

[Dated: Bridgehampton, Long Island, May 4, 1917.]

While quite a little study has been given to the sea breeze in the Temperate Zone I have not yet found any series of observations recording the temperature values at varying distances from the sea coast at any particular time during the sea breeze's progress inland. Records have been kept of its actual velocity and of the velocity of penetration and of its depth, but the temperature factor has been largely covered with the banal generalization that the effect of the breeze is to lower the temperature considerably.

For several years I have kept a Draper recording thermometer during the summer months at the locality known as Mecox, about 2 miles south of the village of Bridgehampton, Long Island, N. Y., and about 100 miles east of New York City. The thermometer has been well sheltered in a covered porch exposed to the southwest. It is distant about a quarter mile from the ocean by the shortest line, but about one-half to three-quarters in the prevailing direction of the sea breeze, that is southwest. The coast at this point and for miles in both directions runs about ENE and WSW. The country is generally level, open farming land for about 4 miles back from the sea, where after already having risen about 60 feet above tide the land breaks into a row of tree-covered hills about 200 to 280 feet in height. The last three summers on Long Island were generally so cool and damp that sea-breeze days were rather rare, but the month of July, 1912, was a sea-breeze month par excellence and most of the observations here recorded were made at that time.

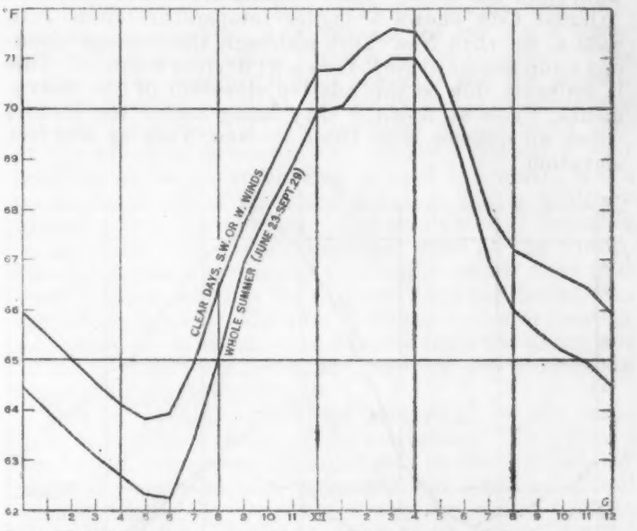


FIG. 1.—Daily temperature curve at "Hopewell," Bridgehampton, L. I. Upper curve based on 70 clear days with southwest or west winds. Lower curve average of the summer, June 23 to Sept. 29, inclusive.

The following series of daily temperature curves shows strikingly the effect of the sea breeze on temperature.[1] Figure 1 shows the average daily curve at Mecox from June 23 to July 21, 1912, a period of almost uninterruptedly fine, warm weather. The double maximum effect is clearly shown. Another interesting feature is the flattening out of the curve between 8 and 9 p. m. This is characteristic of sea-breeze weather, some days even showing a higher temperature at 9 than at 8 p. m. This is due to the cessation of the sea breeze about sun-down and the turn of the wind, usually very light, toward the land. This is not a true land breeze, for the air over the land is warmer than over the sea, but rather a return of the wind to its normal direction.

Figure 2 gives curves which show the average hourly temperatures at certain Weather Bureau stations for the same period June 23—July 21, 1912 in comparison with that at Mecox. This comparison presents interesting features. Besides Mecox, the only other curve that presents a double maximum is that for Atlantic City which gives nearly a triple maximum. This is also a

[1] The author would here acknowledge his obligations to the U. S. Weather Bureau officials at the local offices in Nantucket, Atlantic City, and New York City, all of whom have furnished data used in this study. He is particularly indebted to those at Nantucket and Atlantic City for the large number of individual hourly temperatures furnished.

seacoast station, but the coast there runs about NNE–SSW. so that a sea breeze has to contend more against the prevailing westerly wind, and its effects are therefore more fitful and the lowering of the temperature not as great. New York presents a typical continental curve with a maximum at 2 p. m. The slight dent between 3 and 4 p. m. may be due to a slight sea-breeze effect or to the fact that summer thunderstorms occur about that time. Nantucket is a typical marine station with the maximum near noon. The fact that a marine station like Nantucket has a higher maximum than Mecox, which if not on the continent is nearer to it and part of a much larger land area, may be explained by the fact that the Nantucket station is on the north side of the Island so that the prevailing southwest breeze has to come some distance overland. The Mecox station, as stated, is not over three-quarters of a mile down wind from the shore. Their minima are nearly identical. Atlantic City shows a higher temperature from 7 to 8:30 a. m. than New York although the average noonday temperature at New York is 5½ degrees warmer. This is probably due to the relative elevation of the instruments; those at Atlantic City being nearer the ground warm up quicker than those at New York at 400 feet elevation.

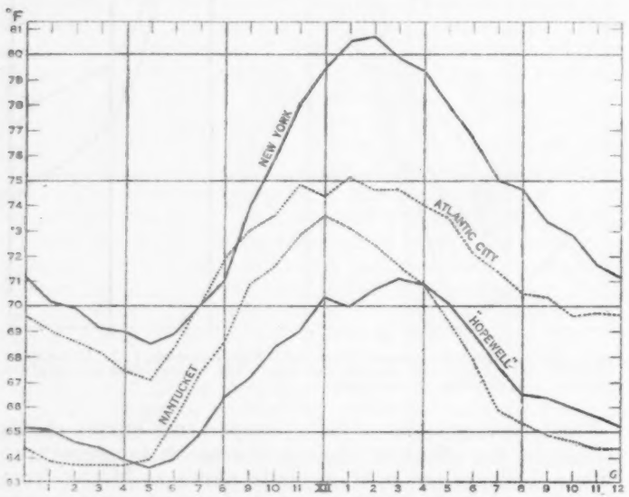


FIG. 2.—Daily temperature curve at "Hopewell," Bridgehampton, L. I., for the period June 23 to July 21, 1912, compared with the corresponding curves for the same period at the Weather Bureau offices in New York, Atlantic City, N. J., and Nantucket, Mass.

While I found only one recorded observation in support, I believe that the sea breeze is felt some little distance aloft before it is on the surface (Am. met. journ., **9**:134). My own reason is that from my point of observation the sound of the sea always precedes the onset of the breeze by several minutes. Normally on sea-breeze days there is but little surf and with a land breeze the sound is inaudible one quarter mile inland. The first symptom of the coming sea breeze is the sound of the surf in the direction from which the breeze will probably make its appearance; the sound waves traverse the already landward moving air at some little altitude, the value of which it would be interesting to determine. The breeze then approaches the surface, or rather its surface contact—which at its inception is a mile or two seaward—gradually advances inland, the rapidity of its advance and its own proper velocity depending on the temperature gradient inland. From my own observation I would say that if the gradient is steep the velocity of the breeze is high but its velocity of penetration [advance] low, if the gradient is more gradual the breeze velocity is less but its penetration [advance] more rapid; in other words, its upward component seems to be proportional to the temperature gradient. That is merely a theory, derived not from any accurate temperature measurements at varying distances inland but as the result of a good many years observation of general conditions. I know that generally speaking the hotter the day the surer we are, at Mecox, of a sea breeze; but if the day be very hot the breeze may not reach Bridgehampton, 2½ miles inland, before 2 or 3 p. m., while the shore enjoys a good breeze all day. I have seen, in mid-afternoon, a difference equalling $93°-76°=17$ degrees between Bridgehampton and the ocean, but that is a very exceptional case for that time of day. In ordinary sea breeze weather the difference at noon is usually about 10°.

An interesting feature seems to be that this temperature gradient is not a constant feature of the summer climate; there are many days when it does not amount to more than 3 or 4 degrees. That is, there are days, and always during hot waves, when the interior becomes greatly overheated and the sea breeze ensues; but on the shore these days are indistinguishable from ordinary summer weather. We do not know it is hot until we go inland, and the farther we go the hotter it gets. I believe that at such times temperature observations taken about 9 a. m. at varying altitudes, both at the coast line and inland, would show a temperature inversion, specially on the coast. In hot-wave weather the atmosphere as a whole over the affected area is superheated, but along the coast the cooling effect of the sea causes a lower temperature below than aloft. This is borne out by observations taken on the U. S. Coast Guard Cutter *Seneca* (MONTHLY WEATHER REVIEW Supplement **3**, 1916), which show a temperature inversion up to 200 meters in both spring and early summer over nearly all waters except the Gulf Stream, this inversion if anything being greater in summer. The following conditions also confirm this: On July 3, 1911, the maximum temperature at Mecox was about 77°; at New York it was 98°; in Boston 103°, and between 90° and 100° at all interior points in the Northeastern States. This is an extreme instance, but it is specially noteworthy that Boston—about 140 miles northeast of Long Island and down the wind, which was quite fresh along the coast—showed a maximum 20 degrees or more above that of coastal points, although Boston is only about 50 miles from the shores of Narragansett Bay. On that day the whole atmosphere was heated and hot-wave weather prevailed, except at low altitudes over the sea and the adjacent coasts. A determination of the height of the sea breeze on such a day and also of the vertical temperature gradient, would be of great interest.

It seems probable that a thorough study of the sea breeze right here at our doors, specially of the temperature factor, might throw a little more light on the whole problem of convectional circulation over continental areas. The fundamental conditions here exist in miniature and while there may be too many local factors to make such a study of great value, we may remember that many a big generalization has been hatched in a test tube.

## INFLUENCE OF THE SEA ON THE CLIMATE OF LONG ISLAND, N. Y.

By ERNEST S. CLOWES.

[Dated: Bridgehampton, Long Island, N. Y., May 4, 1917.]

The influence of the sea on climate has been known in every age, and has been studied by meteorologists in all its manifestations from the monsoon winds of India to sea breezes of our northern coasts; but I doubt if it be generally known that right at our own doors lies a field for study in this direction that presents many interesting possibilities.

Long Island, N. Y., extends from New York Harbor, a distance of 125 miles in an east-northeast direction. For about 70 miles it averages 12 miles wide, the eastern 45 miles forms two peninsulas, the southern one the longer and divided from the northern by a series of irregular bays. On the north the waters of Long Island Sound, averaging 10 to 12 miles wide, lie between it and the Connecticut shore. The southern coast is almost straight and runs in a direction nearly parallel with the prevailing westerly winds. The effect of the sea, especially in Summer, is therefore at its maximum value, for a relatively slight difference in air densities over the land and the adjacent waters is sufficient to deflect the prevailing wind in either direction. The effect of the sea breeze is therefore more marked than in most situations on either the Atlantic or Pacific coasts. The most interesting feature of all this is the notable influence on temperature of relatively small distances from the sea or the Sound. For purposes of illustration I give below the average maxima and minima for the summer months at four different locations on Long Island, as well as at New York City. All but Mecox are from the records of United States Weather Bureau voluntary observers. The Mecox record was made by the author with a Draper recording thermometer placed in a well-ventilated, covered porch with a southwest exposure and protected from the direct rays of the sun at all times, except one or two hours in late afternoon in the latter part of the summer and for which due allowance has been made.

TABLE 1.—*Mean maximum and minimum temperatures, 1912–1916, inclusive.*

| Stations. | Distance from sea. | July. | | August. | | September. | |
|---|---|---|---|---|---|---|---|
| | | Max. | Min. | Max. | Min. | Max. | Min. |
| | *Miles.* | °*F.* | °*F.* | °*F.* | °*F.* | °*F.* | °*F.* |
| Mecox | 0.25 | 73.1 | 62.5 | 73.9 | 62.9 | 70.1 | 57.5 |
| Southampton[1] | 2 | 77.8 | 61.4 | 77.2 | 60.8 | 72.2 | 54.9 |
| Cutchogue[1] | 12 | 80.4 | 62.7 | 79.5 | 62.1 | 75.6 | 56.4 |
| Setauket[2] | 17 | 79.8 | 63.5 | 78.3 | 62.9 | 72.3 | 56.8 |
| New York City | 10 | 81 | 66 | 80 | 65 | 74 | 59 |

[1] Is 2 miles from Long Island Sound. [2] Is a quarter mile from Long Island Sound.

Of the Long Island stations, the one nearest the ocean, Mecox, has by far the lowest mean maximum, and, with the exception of Setauket, the highest mean minimum, the average difference from Setauket being probably less than the probable error of observation. The maxima increase quite regularly according to the distance from deep water. The maxima for Setauket seem high for its short distance from the Sound, but this is explained by its greater distance from the ocean which is the principal factor. For the years 1914–1916, inclusive, a station has been maintained at Medford about in the geographic center of the island and 7 miles or more from ocean or sound. These records indicate a maximum higher than Setauket and about equal to New York, and a low minimum about equal to Southampton. A map of the average July maxima for Long Island probably would show, along the south shore, at least 5 isotherms of 1 degree within a distance of as many miles, a rather remarkable result when it is considered that on the continent such isotherms are usually 60 or 70 miles apart.

The marine influence on the minima is also noticeable, though not to the same degree. For the three summer months Southampton is the lowest, Medford (probably) next, and Mecox, Cutchogue, and Setauket following in the order named. At first sight this seems contradictory as Southampton, 2 miles from the sea, has a lower minimum than Setauket, which is about 17 miles. This is due to the configuration of the land and the prevailing winds which at night, especially in hot weather, are west or northwest. This is sufficient on the north side of the island to overcome any tendency toward a local land breeze at night blowing toward the north, while on the south side of the island it falls in with a tendency toward a land breeze there. The result is that Setauket on the north side, getting the night wind off the Sound, has the highest minimum; Cutchogue comes next and Southampton, which is far removed from the Sound, has the lowest figures. The case of Mecox seems to form an exception, as it is one quarter mile from the ocean and 12 or 14 miles from the Sound, and yet has a minimum nearly as high as Cutchogue.

This is, I think, explained somewhat on the same lines as Seeman's theory of the sea breeze. He held the sea breeze began several miles out to sea because the warm air over the land expanded and acted as a wall against which the incoming breeze could not at first make headway. Similarly, after days when the sea breeze dies at sunset and the land quickly cools by radiation, the air over it shrinks and a sort of false sea breeze, very light compared with the daytime breeze and seldom extending half a mile inland, sets in. It has been the writer's frequent experience to ride at night from the village of Bridgehampton, 2 miles or so inland, when the evening was still, damp, and chilly and low places filled with land fog, down to the coast and to feel about half a mile from the shore a relatively warm, dry air from the sea and no fog about. This effect is specially noticeable late in the summer, and it may be noted that for August the minimum for Mecox is actually higher than Cutchogue and equaling Setauket, while for September it is higher than either and the highest on Long Island. Another possible explanation with regard to Setauket and Cutchogue may be that their high minima may be due to the same reason that New York's is due—that is, to a high average temperature, but the figures for Mecox seem to disprove this in part.

Whatever the explanation, the isotherms of Long Island, especially in summer, might furnish material for further study in which the factors of marine influence on climate might be examined on a small but informing scale.

# KILLING FROST AND LENGTH OF GROWING SEASON IN VARIOUS SECTIONS OF KENTUCKY.

By FERDINAND J. WALZ, Professor of Meteorology.

(Read before the Kentucky Academy of Sciences, May 5, 1917.)

[Dated: Weather Bureau Office, Louisville, Ky.]

ABSTRACT.

In his operations the farmer every season is confronted with risks due to weather and climate. Among the risks that he faces each season are those of damage by late frost in Spring, early frost in Fall, and a possible shortening of the growing season below that needed for the proper development and ripening of his crops. This paper summarizes and presents in the form of tables and charts the results of a study of the dates in Kentucky of the last killing frost in Spring and first killing frost in Fall, and the length of the growing season considered as the number of days between these dates. The records of the regular stations of the U. S. Weather Bureau, and those of the cooperative stations with 20 years or more of record, were carefully examined and analyzed, employing mathematical methods used in the investigation of statistics and probabilities. The average dates of last killing frost in Spring and first killing frost in Fall, the average number of days in the growing season, and the "standard deviations" from these averages were computed for each station, and consequent risks or probabilities determined.

## INTRODUCTION.

In farming operations the farmer every season is confronted with certain climatic and weather risks. Therefore to be successful he should study the climatic conditions of his section, and in some degree at least know the risks that come to him from climatic causes in the raising of any crop. Favorable and unfavorable weather conditions are of the greatest importance to him at all times.

Among the risks that he faces each season is that of damage by late frosts in Spring and early frosts in Fall. This paper presents a summary of the results of a study of the dates of the last killing frost in Spring and the first killing frost in Fall, taken from the records of the various cooperative and other Weather Bureau stations that have been maintained in this State, especially those having a record of 20 years or more.

The cooperative observers are supplied with United States standard thermometers, which are exposed in standardized instrument shelters. The shelter is usually placed over sod with its bottom about 4 feet above ground, bringing the instruments in the shelter to about the height of the eye of the average man.

Frost being the moisture of the air condensed at freezing temperature on plants or other objects near the surface of the earth, the temperature of the surface on which frost appears must therefore necessarily be at or below 32° F. On clear, quiet nights, which are favorable to the formation of frost, the air at the surface of the earth is usually colder than in the thermometer shelter 4 feet or more above the ground, the colder heavier air settling to the lowest point. Also, radiation is greater from a plant surface and from the ground than from the interior of the shelter. Under such conditions, therefore, temperatures within the shelter—and these are the temperatures commonly recorded by our observers—are necessarily several degrees higher than those at the exposed surfaces where frost forms. Obviously, then, killing frosts might occur when the air temperature within the instrument shelter is 35° to 38°F. Regardless of whether or not the temperature in the shelter register as low as 32°F, the Weather Bureau observer records the occurrence of frost in accordance with the following instructions, quoted from Instructions to Voluntary Observers, 1915, page 25, section 60:

*Frost.*—Occurrence of first and last frost of the growing season should be specially noted.

The terms descriptive of frost will be as follows:

*Light*, to indicate a frost that has no destructive effect, although tender plants and vines in exposed places may be injured. *Heavy*, to indicate a frost that in itself is severer than a light frost—that is, the deposit of frost is heavier and the temperature falls to a lower point, although the staple products of the locality may not have been generally destroyed. *Killing*, to indicate a frost that is generally destructive of vegetation and the staple products of the locality.

### *Harmonizing of frost records.*

In (making) this study frost records of the various stations were carefully examined and harmonized with the minimum temperatures, general weather conditions, precipitation, frost at neighboring stations, maximum temperature of day previous, location of station and its elevation, and the topography of the country. The frost records of all stations for each year were studied together and carefully charted to harmonize them as far as possible. Whenever the temperature was 32° in Spring and no killing frost was reported afterward, that date was taken as the last killing frost of the season. Also, in Fall the occurrence of the first temperature of 32°F. was taken as the date of the first killing frost, provided no record of killing frost had been made previous to that date. An interesting fact is brought out by Prof. Fassig [1] namely that Fall records of first killing frost are more accurate and reliable than Spring records of last killing frost, because an observer is more apt to note and record the first occurrence of an event of this kind than he is the last occurrence, unless the last occurrence is unusually pronounced.

The records have been studied and analyzed, employing mathematical methods used in the investigation of statistics and probabilities. The average dates of last killing frost in Spring and first killing frost in Fall have been carefully computed; also the standard deviation.[1]

### *Average or normal condition.*

Beside the usual units of measure of the elements that constitute climate, such as degrees of temperature, inches of precipitation, miles per hour for wind movement, percentage of cloudiness, etc., it is found necessary to establish some measure or condition of each element as a base of reference with which to compare the many irregular variations in the actual observation of these elements. The base of reference usually chosen is the average or normal condition, determined by reducing the recorded values of the element to an arithmetical mean. This average does not express the usual, or even expected condition; also rarely is it the condition of greatest frequency. But it does afford a convenient basis for determining the general character of an element in any locality, in that it is a value about which actual values fluctuate. To convey a definite idea of the real

[1] Without particularizing I wish to refer to the following recent papers dealing with the problems of the present paper:

*Reed, W. G. & Tolley, H. R.* Weather as a business risk in farming. Geogr. rev., New York, 1916, 2:48-53; Abstract in this REVIEW, June, 1916.

*Reed, W. G.* Probable growing season, this REVIEW, September, 1916.

*Spillman, W. J. and others.* Average interval curve and its application to meteorological phenomena, this REVIEW, April, 1916.

*Martin, C. F.* Elementary notes on least squares, etc., for meteorology and agriculture, this REVIEW, April, 1916.

*Fassig, O. L.* Period of safe plant growth in Maryland and Delaware, this REVIEW, March, 1914.

*Wilson, Wilford M.* Frosts in New York. Cornell agric. exper. sta., Bulletin no. 316. Ithaca, N. Y., 1912.

character of a locality as regards any single climatic element, a statement of the average value of the element must necessarily be attended by additional information as to the magnitude and frequency of departures from that average.

*Standard deviation.*

A measure of the dispersion or variation of the individual observations in any series of observations or data, from the average or mean value, is supplied in the "standard deviation" or those values of the departure which locate the points on a *normal frequency* curve where the curvature changes from convex to concave; that is, points of inflection (see C. F. Marvin, op. cit.).

In the method of least squares the value of the standard deviation is given by the formula, $\sigma = \sqrt{\frac{\Sigma x^2}{n}}$, where $\sigma$ is the standard deviation; $\Sigma x^2$ the sum of the squares of the departures from the true mean, and $n$ the total number of observations. In practical calculation the formula as modified by Prof. Marvin is preferable. This formula is $\sigma = \sqrt{\frac{[x^2]}{n} - \left(\frac{[x]}{n}\right)^2}$, where $[x]$ is the algebraic sum of the departures taken from a convenient base number—usually the average taken to the nearest whole number—and $[x^2]$ is the sum of the squares of these departures. The standard deviations given in the tables herewith were computed by means of this modified formula.

Values of the ratio of any departure, $x$, to the standard deviation for assumed frequencies of $x$ (expressed in percentage) were taken from the article by Spillman and others (loc. cit.), the average interval being the reciprocal of the normal frequency or probability of the occurrence of an event.

These values are given in the following table:

TABLE 1.

| Probability. | Frequency. | Average interval. | Value of $x/\sigma$ |
|---|---|---|---|
| *Per cent.* | | *Years.* | |
| 50 | 1 year in 2 | 2 | 0 ($x=0$) |
| 40 | 2 years in 5 | 2½ | 0.25 |
| 33⅓ | 1 year in 3 | 3 | 0.48 |
| 25 | 1 year in 4 | 4 | 0.67 |
| 20 | 1 year in 5 | 5 | 0.84 |
| 10 | 1 year in 10 | 10 | 1.28 |
| 5 | 1 year in 20 | 20 | 1.64 |

The chance of frost occurrence, by the theory of probability, is given in the following table from W. G. Reed in MONTHLY WEATHER REVIEW, September, 1916, page 511.

TABLE 2.—*Chance of frost occurrence (20-year record) when the standard deviations are known.*

| Chance of frost. | Chance of safety. | Spring. | Fall. |
|---|---|---|---|
| *Per cent.* | *Per cent.* | *Date.* | *Date.* |
| 50 | 50 | $A_s$ | $A_f$ |
| 40 | 60 | $A_s+0.25\sigma_s$ | $A_f-0.25\sigma_f$ |
| 33⅓ | 66⅔ | $A_s+0.48\sigma_s$ | $A_f-0.48\sigma_f$ |
| 25 | 75 | $A_s+0.67\sigma_s$ | $A_f-0.67\sigma_f$ |
| 20 | 80 | $A_s+0.84\sigma_s$ | $A_f-0.84\sigma_f$ |
| 10 | 90 | $A_s+1.28\sigma_s$ | $A_f-1.28\sigma_f$ |
| 5 | 95 | $A_s+1.64\sigma_s$ | $A_f-1.64\sigma_f$ |

$A_s$ = average date of last killing frost in Spring.
$\sigma_s$ = standard deviation.
All fractions are added in Spring and dropped in Fall.
$A_f$ = average date of firs killing frost in Fall.
$\sigma_f$ = standard deviation.

RISK OF DESTRUCTIVE FROST IN KENTUCKY.

As a rule the risk of a destructive frost is not so great for farmers in Kentucky as it is for those in many other States, particularly in those States farther north and in those farther south. In Kentucky most of the principal crops are usually planted after the average time of killing frost in Spring, and they mature or are harvested before the average date of killing frost in Fall, the period between these dates usually being of sufficient length for the growing and maturing of most of the staple crops. Occasionally, however, favorable conditions in Spring lead to early planting and the consequent risk of damage from spring frost; again, unfavorable conditions of weather or soil delay planting, which in turn increases the risk of damage from an early fall frost. In Kentucky, killing frosts in Spring refer chiefly to damage to fruit, strawberries, and early garden truck—corn and tobacco being usually not yet planted. In the Fall damage from killing frost refers almost entirely to corn and tobacco; its occurrence usually ends the season for those crops. It not infrequently happens, however, as was the case during the past two years, that these crops are matured and well out of danger before the occurrence of the first freezing temperature or of destructive frost. It should be recognized that the farmer should know and heed the risk he runs and the chances he takes from probable damage by frosts, both in Spring and Fall.

LENGTH OF THE GROWING SEASON.

The length of the growing season, or the period of safety for plant growth, is generally considered to be the number of days in each season between the date of the last killing frost in Spring and that of the first killing frost in Fall; also the average length of the growing season as usually determined is the number of days between the *average* date of the last killing frost in Spring and the *average* date of the first killing frost in Fall. In this study the length of the growing season agrees with the above definition, but the *average* length of the growing season was computed by summing the actual number of days between the date of last and date of first killing frost in each season and taking the mean.

As the chance of safety from killing frost in Spring is 50 per cent when the average date of last killing frost arrives, and also the chance of safety in Fall is 50 per cent when the average date for first killing frost arrives, the chance for safety for the days between these dates is $\frac{50}{100} \times \frac{50}{100}$, or only 25 per cent—a chance that could not reasonably be taken for crops requiring the full growing season to mature. The length of a growing season that has only a 20 per cent risk, or one that is practically sure in four years out of five, was therefore computed. (See Table 2 and fig. 4.) Such a growing season is obviously the same as one in which the risk from killing frost in Spring is 10 per cent, and the risk from killing frost in Fall is also 10 per cent.

Tables 3 and 4 and figures 1 to 4, accompanying this paper, summarize and bring together in a practical way for easy reference results of this frost study.

The map presented in figure 1 shows that the average date of the last killing frost in Spring is latest (Apr. 20) over the central plateau section of the State, comprising the counties from Green, Marion, and Boyle eastward to the Cumberland Mountains and the extreme northeastern

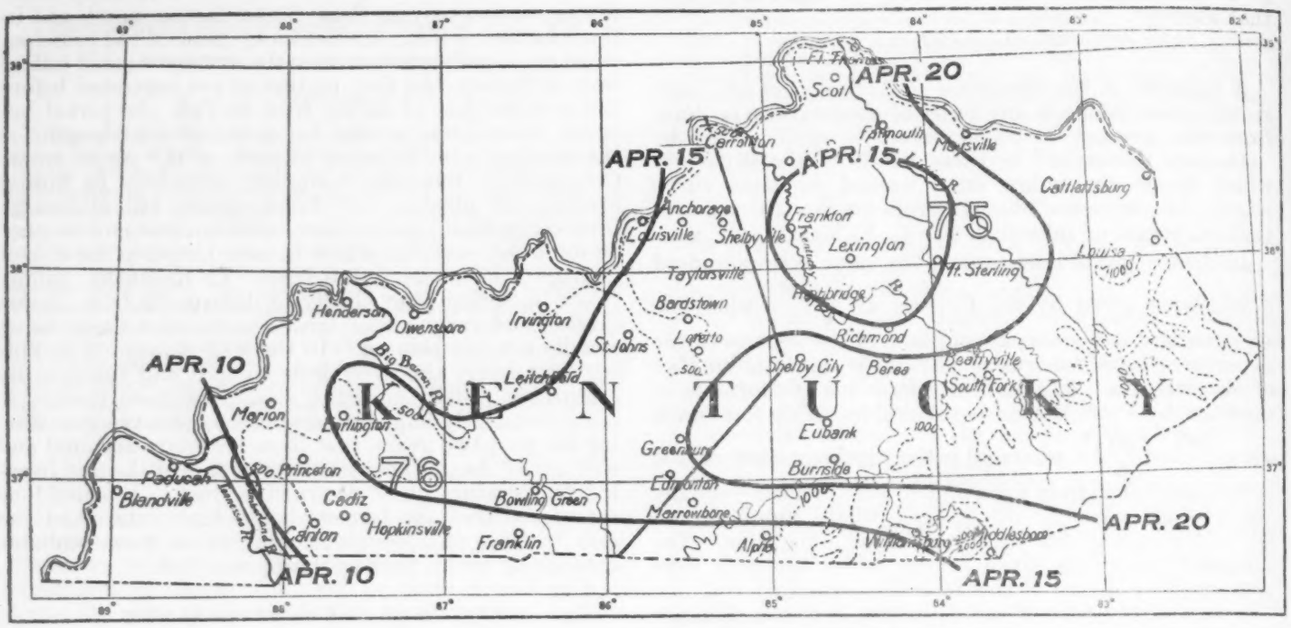


FIG. 1.—Map of Kentucky showing average dates of last killing frost in Spring.
General altitudes above sealevel are shown by the contours for 500 and for 1,000 feet (dotted lines).

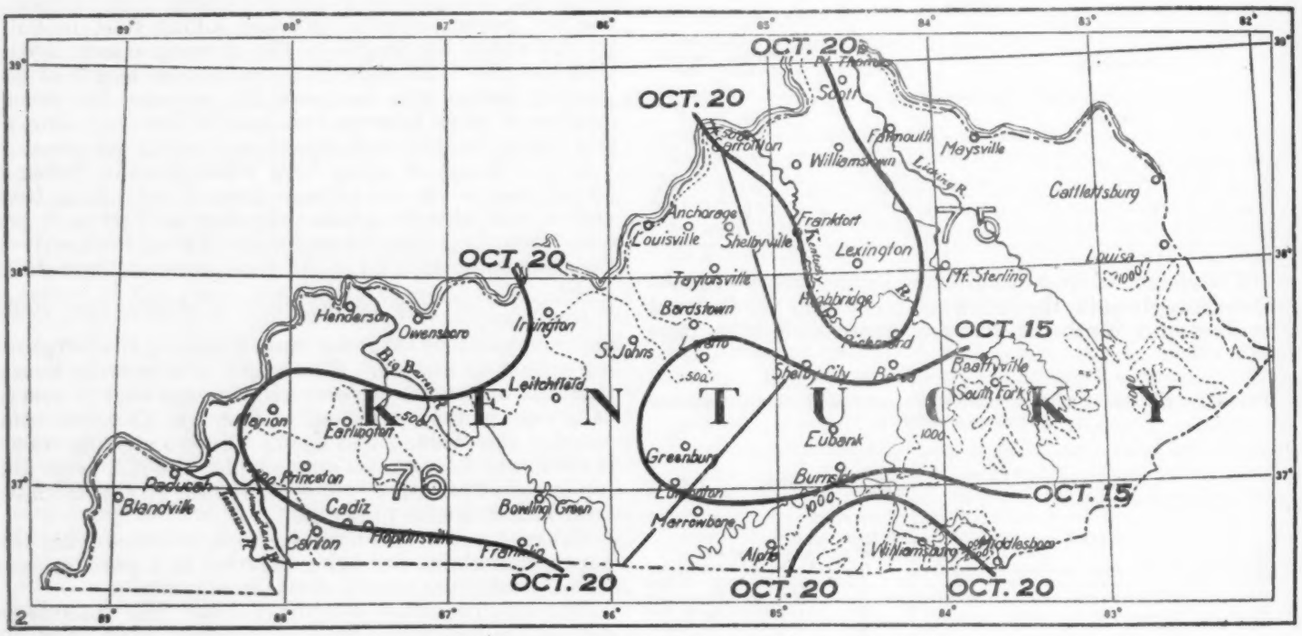


FIG. 2.—Map of Kentucky showing average dates of first killing frost in Fall.

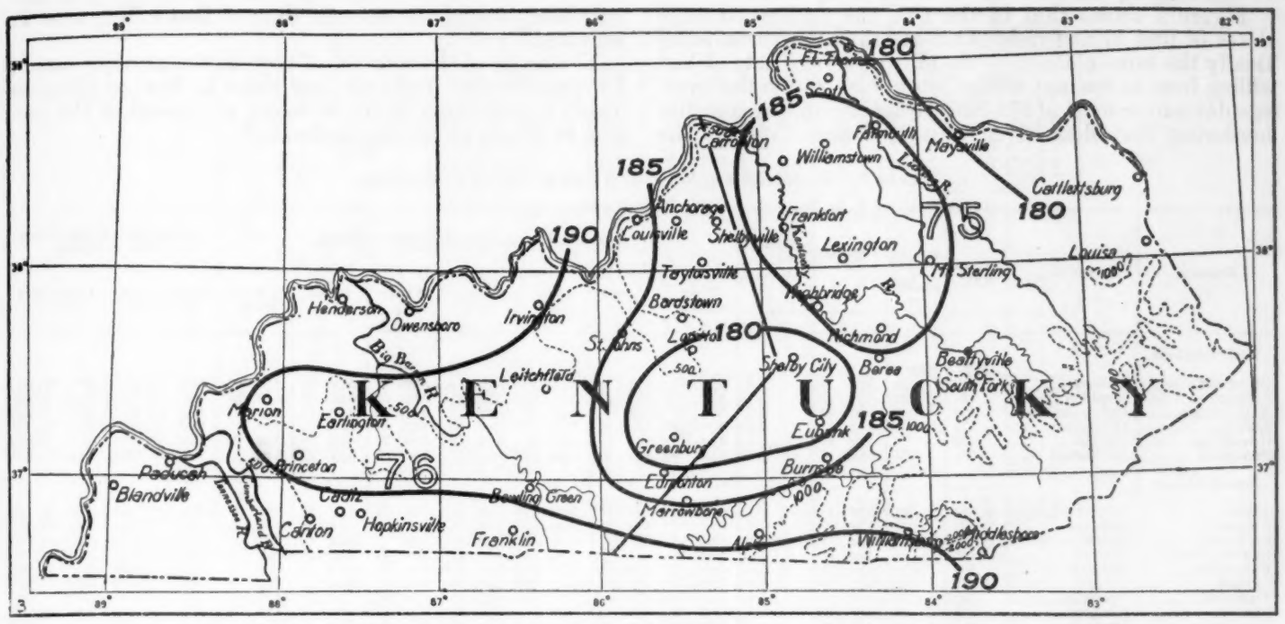


FIG. 3.—Map of Kentucky showing average number of days in the growing season, i. e., the number of consecutive days free from killing frost.

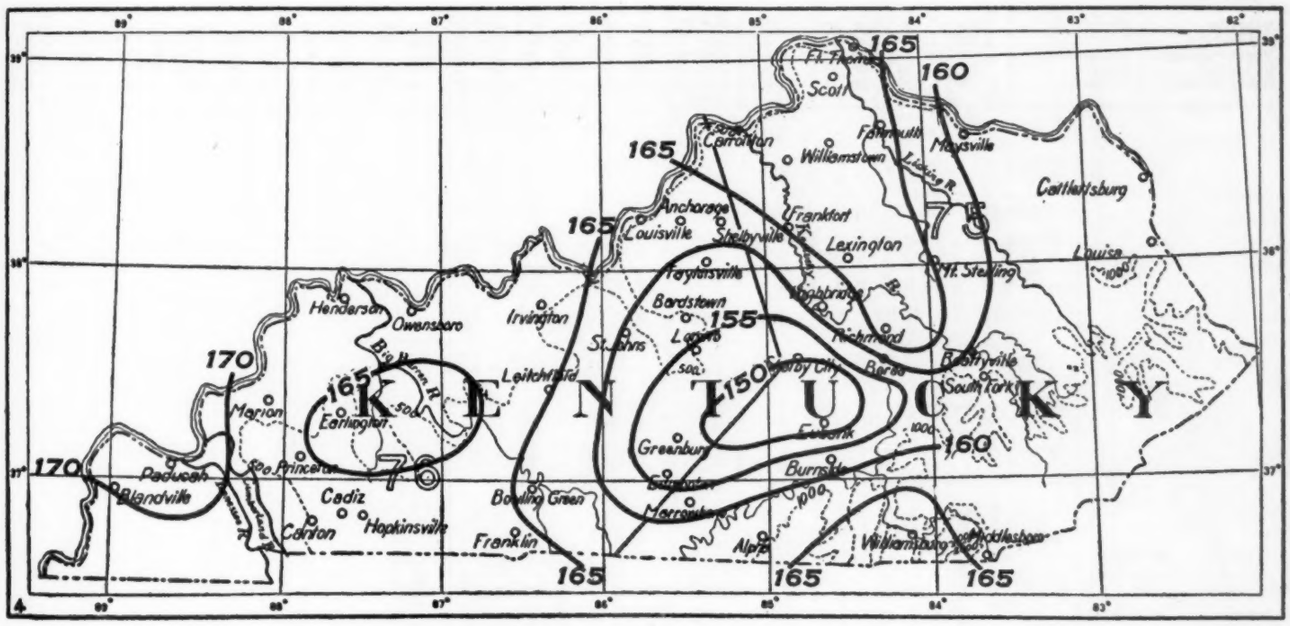


FIG. 4.—Map showing the number of days to be expected in the growing season, 4 years out of 5.

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counties from Bracken and Fleming to Boyd. This date is earliest (Apr. 9 to 12) in the extreme western counties, in the counties bordering western Tennessee, and in the counties along the Ohio River as far as up Meade.

Figure 2 shows that in the Fall the earliest average dates of first killing frost (Oct. 13–15) occur over practically the same plateau as the latest average date of last killing frost in Spring; while October 20–23 are the average dates over most of the Blue Grass region, the counties bordering the Ohio River west of Boone County, the southern tier of counties, and the extreme western counties.

The average length of the growing season, ranging from 176 to 198 days, closely follows in geographic distribution that of the average date of first killing frost in autumn.

The range of the number of days in the growing season for each station probable four years in five, as given in Table 4, may reasonably be taken as typical of the section in which the station is located.

TABLE 3.—*Probabilities of last killing frost in Spring in Kentucky.*

| Stations. | Counties. | Elevation. | Length of record. | Average date | Standard deviation | Probable latest dates of killing frost in Spring. | | | | | | | Actual dates of last killing frosts in Spring. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $A_s$ | $\sigma_s$ | Even chance. | 2 years in 5. | 1 year in 3. | 1 year in 4. | 1 year in 5. | 1 year in 10. | 1 year in 20. | Earliest date on record. | Latest date on record. |
| *Western division.* | | *Feet.* | *Years.* | | | | | | | | | | | |
| Blandville | Ballard | 445 | 23 | Apr. 10 | 9.2 | Apr. 10 | Apr. 13 | Apr. 15 | Apr. 17 | Apr. 18 | Apr. 22 | Apr. 26 | Mar. 25, 1912 | May 14, 1895 |
| Earlington | Hopkins | 420 | 24 | Apr. 15 | 8.2 | Apr. 15 | Apr. 17 | Apr. 19 | Apr. 21 | Apr. 22 | Apr. 26 | Apr. 29 | Mar. 29, 1913 | May 1, 1908 |
| Hopkinsville | Christian | 524 | 21 | Apr. 12 | 8.8 | Apr. 12 | Apr. 14 | Apr. 17 | Apr. 18 | Apr. 20 | Apr. 24 | Apr. 27 | Mar. 29, 1913 | May 2, 1909 |
| Marion | Crittenden | 571 | 23 | Apr. 12 | 9.1 | Apr. 12 | Apr. 15 | Apr. 17 | Apr. 18 | Apr. 20 | Apr. 24 | Apr. 27 | Mar. 25, 1912 | May 14, 1895 |
| Owensboro | Daviess | 479 | 20 | Apr. 12 | 9.5 | Apr. 12 | Apr. 15 | Apr. 17 | Apr. 19 | Apr. 20 | Apr. 25 | Apr. 28 | Mar. 26, 1912 | May 2, 1907 |
| Paducah | McCracken | 341 | 24 | Apr. 9 | 8.5 | Apr. 9 | Apr. 12 | Apr. 13 | Apr. 15 | Apr. 16 | Apr. 20 | Apr. 23 | Mar. 25, 1912 | Apr. 25, 1910 |
| *Central division.* | | | | | | | | | | | | | | |
| Alpha | Clinton | 811 | 23 | Apr. 13 | 7.5 | Apr. 13 | Apr. 15 | Apr. 17 | Apr. 18 | Apr. 20 | Apr. 25 | Apr. 26 | Mar. 29, 1913 | Apr. 24, 1910 |
| Anchorage | Jefferson | 700 | 22 | Apr. 18 | 8.6 | Apr. 18 | Apr. 21 | Apr. 23 | Apr. 24 | Apr. 26 | Apr. 29 | May 2 | Apr. 1, 1913 | May 14, 1895 |
| Bardstown | Nelson | 637 | 20 | Apr. 18 | 10.4 | Apr. 18 | Apr. 21 | Apr. 23 | Apr. 25 | Apr. 27 | May 2 | May 5 | Mar. 29, 1913 | May 3, 1911 |
| Bowling Green | Warren | 500 | 24 | Apr. 16 | 9.3 | Apr. 16 | Apr. 19 | Apr. 21 | Apr. 23 | Apr. 24 | Apr. 28 | May 2 | Mar. 29, 1913 | May 14, 1895 |
| Edmonton | Metcalfe | 600 | 24 | Apr. 19 | 8.9 | Apr. 19 | Apr. 22 | Apr. 24 | Apr. 25 | Apr. 27 | May 1 | May 4 | Mar. 29, 1913 | May 14, 1895 |
| Eubank | Pulaski | 1,177 | 22 | Apr. 22 | 8.5 | Apr. 22 | Apr. 25 | Apr. 26 | Apr. 28 | Apr. 30 | May 3 | May 6 | Apr. 1, 1913 | May 15, 1895 |
| Frankfort | Franklin | 560 | 21 | Apr. 14 | 9.1 | Apr. 14 | Apr. 16 | Apr. 19 | Apr. 21 | Apr. 22 | Apr. 26 | Apr. 29 | Mar. 25, 1912 | May 1, 1908 |
| Franklin | Simpson | 691 | 23 | Apr. 12 | 8.4 | Apr. 12 | Apr. 14 | Apr. 16 | Apr. 18 | Apr. 19 | Apr. 23 | Apr. 26 | Mar. 28, 1897 | Apr. 30, 1908 |
| Greensburg | Green | 581 | 24 | Apr. 20 | 8.7 | Apr. 20 | Apr. 22 | Apr. 23 | Apr. 26 | Apr. 28 | May 1 | May 5 | Apr. 4, 1896 | May 5, 1907 |
| Irvington | Breckenridge | 646 | 20 | Apr. 12 | 9.1 | Apr. 12 | Apr. 15 | Apr. 17 | Apr. 18 | Apr. 20 | Apr. 24 | Apr. 27 | Mar. 26, 1912 | May 1, 1908 |
| Leitchfield | Grayson | 635 | 21 | Apr. 15 | 9.1 | Apr. 15 | Apr. 18 | Apr. 20 | Apr. 21 | Apr. 23 | Apr. 27 | Apr. 30 | Mar. 29, 1913 | May 2, 1909 |
| Lexington | Fayette | 989 | 29 | Apr. 16 | 10.0 | Apr. 16 | Apr. 19 | Apr. 21 | Apr. 23 | Apr. 25 | Apr. 29 | May 3 | Mar. 29, 1913 | May 20, 1894 |
| Loretto | Marion | 681 | 20 | Apr. 19 | 7.8 | Apr. 19 | Apr. 21 | Apr. 23 | Apr. 25 | Apr. 26 | Apr. 29 | May 2 | Apr. 5, 1903 | May 3, 1911 |
| Louisville | Jefferson | 525 | 40 | Apr. 10 | 8.9 | Apr. 10 | Apr. 12 | Apr. 14 | Apr. 16 | Apr. 18 | Apr. 21 | Apr. 25 | Mar. 25, 1878 | May 14, 1895 |
| St. John | Hardin | 777 | 21 | Apr. 17 | 9.7 | Apr. 17 | Apr. 20 | Apr. 22 | Apr. 24 | Apr. 25 | Apr. 30 | May 3 | Mar. 29, 1913 | May 9, 1906 |
| Scott | Kenton | 900 | 20 | Apr. 18 | 5.8 | Apr. 18 | Apr. 20 | Apr. 21 | Apr. 22 | Apr. 23 | Apr. 25 | Apr. 28 | Apr. 8, 1898 | May 1, 1903 |
| Shelby City | Boyle | 1,087 | 24 | Apr. 21 | 9.1 | Apr. 21 | Apr. 24 | Apr. 26 | Apr. 28 | Apr. 29 | May 3 | May 6 | Apr. 5, 1903 | May 9, 1906 |
| Shelbyville | Shelby | 825 | 24 | Apr. 17 | 8.1 | Apr. 17 | Apr. 19 | Apr. 21 | Apr. 23 | Apr. 24 | Apr. 28 | May 1 | Apr. 5, 1903 | May 14, 1895 |
| *Eastern division.* | | | | | | | | | | | | | | |
| Maysville | Mason | 524 | 21 | Apr. 21 | 10.0 | Apr. 21 | Apr. 24 | Apr. 26 | Apr. 28 | Apr. 30 | May 4 | May 7 | Apr. 3, 1896 | May 15, 1910 |
| Middlesboro | Bell | 1,128 | 24 | Apr. 16 | 8.0 | Apr. 16 | Apr. 18 | Apr. 20 | Apr. 22 | Apr. 23 | Apr. 27 | Apr. 30 | Mar. 30, 1894 | May 3, 1911 |
| Mount Sterling | Montgomery | 930 | 24 | Apr. 15 | 8.5 | Apr. 15 | Apr. 18 | Apr. 19 | Apr. 21 | Apr. 22 | Apr. 26 | Apr. 29 | Mar. 30, 1913 | May 15, 1895 |
| Richmond | Madison | 926 | 23 | Apr. 15 | 8.7 | Apr. 15 | Apr. 18 | Apr. 20 | Apr. 21 | Apr. 23 | Apr. 27 | Apr. 30 | Mar. 30, 1913 | May 2, 1909 |
| Williamsburg | Whitley | 939 | 20 | Apr. 15 | 8.2 | Apr. 15 | Apr. 17 | Apr. 19 | Apr. 21 | Apr. 22 | Apr. 26 | Apr. 29 | Apr. 4, 1908 | May 2, 1909 |

TABLE 4.—*Probabilities of first killing frost in Fall in Kentucky and probable lengths of growing seasons there.*

| Stations. | Average date. | Standard deviation. | Probable earliest dates of killing frost in Fall. | | | | | | | Actual dates of first killing frosts in Fall. | | Length of growing season.* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Even chance. | 2 years in 5. | 1 year in 3. | 1 year in 4. | 1 year in 5. | 1 year in 10. | 1 year in 20. | Earliest date on record. | Latest date on record. | Average. | Standard deviation. | 4 years in 5. | | Longest and year. | Shortest and year. |
| | | | | | | | | | | | | | | Practically sure. | Range of probability. | | |
| | $A_f$ | $\sigma_f$ | | | | | | | | | | $l$ | $\sigma_l$ | | | | |
| *Western division.* | | | | | | | | | | | | *Days.* | | *Days.* | *Days.* | *Days.* | *Days.* |
| Blandville | Oct. 20 | 9.0 | Oct. 20 | Oct. 18 | Oct. 16 | Oct. 14 | Oct. 13 | Oct. 9 | Oct. 5 | Sept. 30, 1899 | Nov. 8, 1900 | 194 | 13.2 | 170 | 183 to 205 | 216, 1897 | 140, 1895 |
| Earlington | Oct. 17 | 9.6 | Oct. 17 | Oct. 15 | Oct. 13 | Oct. 11 | Oct. 9 | Oct. 5 | Oct. 2 | Sept. 30, 1899 | Nov. 3, 1900 | 185 | 14.4 | 162 | 177 to 197 | 216, 1913 | 153, 1908 |
| Hopkinsville | Oct. 20 | 8.4 | Oct. 20 | Oct. 18 | Oct. 16 | Oct. 15 | Oct. 13 | Oct. 10 | Oct. 7 | Sept. 30, 1899 | Nov. 6, 1900 | 191 | 12.0 | 169 | 181 to 201 | 207, 1908 | 163, 1909 |
| Marion | Oct. 16 | 7.1 | Oct. 16 | Oct. 14 | Oct. 13 | Oct. 12 | Oct. 10 | Oct. 7 | Oct. 5 | Sept. 30, 1899 | Oct. 28 {1908 1910} | 187 | 11.5 | 166 | 177 to 197 | 213, 1912 | 140, 1895 |
| Owensboro | Oct. 23 | 9.9 | Oct. 23 | Oct. 21 | Oct. 19 | Oct. 17 | Oct. 15 | Oct. 11 | Oct. 7 | Sept. 30, 1899 | Nov. 9, 1900 | 194 | 14.2 | 169 | 182 to 206 | 222, 1912 | 163, 1909 |
| Paducah | Oct. 23 | 9.6 | Oct. 23 | Oct. 21 | Oct. 19 | Oct. 17 | Oct. 15 | Oct. 11 | Oct. 8 | Sept. 30, 1899 | Nov. 8, 1900 | 198 | 12.1 | 174 | 190 to 206 | 221, 1897 | 180, 1907 |
| *Central division.* | | | | | | | | | | | | | | | | | |
| Alpha | Oct. 18 | 13.3 | Oct. 18 | Oct. 15 | Oct. 12 | Oct. 10 | Oct. 8 | Oct. 2 | Sept. 27 | Sept. 14, 1902 | Nov. 14, 1900 | 188 | 13.1 | 162 | 177 to 199 | 216, 1913 | 159, 1902 |
| Anchorage | Oct. 17 | 7.6 | Oct. 17 | Oct. 15 | Oct. 14 | Oct. 12 | Oct. 11 | Oct. 8 | Oct. 5 | Sept. 30, 1899 | Oct. 30, 1897 | 181 | 11.2 | 162 | 178 to 190 | 203, 1913 | 154, 1908 |
| Bardstown | Oct. 17 | 7.9 | Oct. 17 | Oct. 15 | Oct. 14 | Oct. 12 | Oct. 11 | Oct. 7 | Oct. 4 | Sept. 27, 1899 | Oct. 31, 1908 | 182 | 11.1 | 158 | 173 to 191 | 206, 1913 | 155, 1906 |
| Bowling Green | Oct. 19 | 8.1 | Oct. 19 | Oct. 17 | Oct. 15 | Oct. 14 | Oct. 13 | Oct. 9 | Oct. 6 | Sept. 30, 1899 | Oct. 29 {1897 1902} | 187 | 12.4 | 164 | 177 to 197 | 205, 1913 | 140, 1895 |
| Edmonton | Oct. 15 | 11.4 | Oct. 15 | Oct. 13 | Oct. 10 | Oct. 8 | Oct. 6 | Oct. 1 | Sept. 27 | Sept. 14, 1902 | Nov. 4, 1900 | 180 | 14.3 | 153 | 168 to 192 | 206, {1900 1913} | 154, 1902 |
| Eubank | Oct. 13 | 11.5 | Oct. 13 | Oct. 11 | Oct. 8 | Oct. 6 | Oct. 3 | Sept. 29 | Sept. 25 | Sept. 14, 1902 | Nov. 4, 1900 | 176 | 13.2 | 149 | 165 to 187 | 203, 1913 | 154, 1902 |
| Frankfort | Oct. 20 | 8.6 | Oct. 20 | Oct. 18 | Oct. 16 | Oct. 15 | Oct. 13 | Oct. 9 | Oct. 6 | Sept. 30, 1899 | Nov. 6, 1900 | 189 | 12.8 | 166 | 178 to 200 | 213, 1912 | 170, 1906 |
| Franklin | Oct. 20 | 9.2 | Oct. 20 | Oct. 18 | Oct. 16 | Oct. 14 | Oct. 13 | Oct. 9 | Oct. 5 | Sept. 30, 1899 | Nov. 4, 1907 | 191 | 14.0 | 169 | 179 to 203 | 216, 1897 | 155, 1908 |
| Greensburg | Oct. 14 | 12.0 | Oct. 14 | Oct. 11 | Oct. 9 | Oct. 6 | Oct. 4 | Sept. 29 | Sept. 25 | Sept. 14, 1902 | Nov. 4, 1900 | 178 | 14.0 | 151 | 166 to 190 | 204, 1900 | 154, {1902 1908} |
| Irvington | Oct. 19 | 7.8 | Oct. 19 | Oct. 17 | Oct. 15 | Oct. 14 | Oct. 13 | Oct. 9 | Oct. 5 | Sept. 30, 1899 | Oct. 31, 1908 | 190 | 10.3 | 168 | 181 to 199 | 212, 1912 | 174, 1899 |
| Leitchfield | Oct. 20 | 8.6 | Oct. 20 | Oct. 18 | Oct. 16 | Oct. 14 | Oct. 12 | Oct. 9 | Oct. 6 | Sept. 30, 1899 | Nov. 6, 1900 | 189 | 10.7 | 165 | 180 to 198 | 206, {1900 1913} | 164, 1909 |
| Lexington | Oct. 25 | 13.1 | Oct. 25 | Oct. 22 | Oct. 19 | Oct. 17 | Oct. 14 | Oct. 9 | Oct. 4 | Sept. 30 {1895 1899} | Nov. 27, 1902 | 192 | 14.1 | 163 | 180 to 204 | 233, 1902 | 142, 1894 |
| Loretto | Oct. 14 | 11.5 | Oct. 14 | Oct. 12 | Oct. 9 | Oct. 7 | Oct. 5 | Sept. 30 | Sept. 26 | Sept. 14, 1902 | Oct. 30, 1897 | 178 | 12.2 | 154 | 168 to 188 | 201, 1903 | 154, {1902 1908} |
| Louisville | Oct. 22 | 10.3 | Oct. 22 | Oct. 20 | Oct. 17 | Oct. 15 | Oct. 14 | Oct. 9 | Oct. 5 | Sept. 30, 1899 | Nov. 14, 1882 | 195 | 14.1 | 171 | 183 to 207 | 223, 1915 | 140, 1895 |
| St. John | Oct. 17 | 7.8 | Oct. 17 | Oct. 15 | Oct. 14 | Oct. 12 | Oct. 11 | Oct. 7 | Oct. 5 | Sept. 27, 1899 | Oct. 30, 1897 | 183 | 11.6 | 160 | 176 to 190 | 206, 1913 | 155, 1906 |
| Scott | Oct. 19 | 8.8 | Oct. 19 | Oct. 17 | Oct. 15 | Oct. 13 | Oct. 11 | Oct. 8 | Oct. 5 | Sept. 30, 1899 | Oct. 30, 1908 | 184 | 9.4 | 166 | 176 to 192 | 202, 1898 | 164, 1901 |
| Shelby City | Oct. 15 | 11.1 | Oct. 15 | Oct. 13 | Oct. 10 | Oct. 8 | Oct. 6 | Oct. 1 | Sept. 27 | Sept. 14, 1902 | Oct. 30, 1897 | 177 | 14.9 | 151 | 165 to 189 | 202, {1898 1903} | 152, 1902 |
| Shelbyville | Oct. 17 | 8.4 | Oct. 17 | Oct. 15 | Oct. 13 | Oct. 12 | Oct. 10 | Oct. 7 | Oct. 3 | Sept. 30, 1899 | Oct. 30, 1897 | 183 | 12.3 | 162 | 173 to 193 | 202, 1903 | 139, 1895 |
| *Eastern division.* | | | | | | | | | | | | | | | | | |
| Maysville | Oct. 18 | 7.9 | Oct. 18 | Oct. 16 | Oct. 15 | Oct. 13 | Oct. 12 | Oct. 8 | Oct. 5 | Sept. 30, 1899 | Oct. 28, 1910 | 179 | 13.0 | 157 | 168 to 190 | 201, 1898 | 154, {1906 1908} |
| Middlesboro | Oct. 19 | 10.1 | Oct. 19 | Oct. 17 | Oct. 15 | Oct. 13 | Oct. 11 | Oct. 7 | Oct. 3 | Sept. 21, 1897 | Nov. 6, 1900 | 184 | 14.0 | 163 | 172 to 196 | 210, 1908 | 156, 1897 |
| Mount Sterling | Oct. 19 | 8.7 | Oct. 19 | Oct. 17 | Oct. 15 | Oct. 14 | Oct. 12 | Oct. 8 | Oct. 5 | Sept. 30, 1899 | Oct. 31, 1908 | 186 | 13.8 | 165 | 174 to 198 | 210, 1908 | 138, 1895 |
| Richmond | Oct. 20 | 8.5 | Oct. 20 | Oct. 18 | Oct. 16 | Oct. 14 | Oct. 13 | Oct. 10 | Oct. 7 | Sept. 30, 1899 | Nov. 2, 1911 | 190 | 12.0 | 166 | 180 to 200 | 206, 1911 | 164, 1909 |
| Williamsburg | Oct. 22 | 8.7 | Oct. 22 | Oct. 20 | Oct. 18 | Oct. 17 | Oct. 15 | Oct. 11 | Oct. 8 | Sept. 30, 1899 | Nov. 6, 1900 | 190 | 11.4 | 168 | 180 to 200 | 214, 1900 | 168, 1899 |

*Number of days between the last killing frost in Spring and the first killing frost in Fall.

## RELATION BETWEEN TEMPERATURE AND CROPS.

By DEWEY ALSDORF SEELEY, Local Forecaster.

(Abstract of paper read before the Michigan Academy of Sciences, Ann Arbor, Mich., March 29, 1917.)

### INTRODUCTION.

The determination of definite relationships between weather conditions and the growth of crops is difficult on account of the complex influences involved. These are so intimately related that the isolation of any one factor is practically impossible, and we are still without exact statements of the plant requirements of any single climatological element, with the possible exception of rainfall. Smith (1) and Briggs & Shantz (2) have made some investigations of the rainfall requirements which are interesting and helpful, but further information, even in this connection, is needed.

At present, as Swingle (3) has stated, "The life history requirements and the limits of the power to resist unfavorable environmental conditions are far better known for many microscopic lower plants, such as bacteria, fungi, and algæ * * *, than for the most important crop plants whose culture provides employment for tens of millions of human beings, and whose products constitute the daily food of hundreds of millions."

The particular weather element with which this paper deals is that of temperature. What is needed is a determination of the heat requirements of each crop and a method of evaluating air temperature records in terms of their efficiency to meet these requirements, and some suggestions are made herein along the latter line. When the whole problem is finally worked out it should be possible to state the normal efficiency of each locality, as regards heat, to meet the needs of each crop, possibly in terms of percentage of perfection.

### METHODS OF INVESTIGATION.

Prof. Cleveland Abbe (4) in his "First report on the relation between climates and crops," compiled a complete survey of all investigations which had been undertaken along this line up to 1891. For the most part the temperature studies were carried on by means of what has been termed the "summation method." This at first consisted in adding together the daily mean temperatures during the life history of any crop—say from the time of planting to harvesting corn—the idea being that a certain number of degrees of temperature would produce the same stage of development from year to year. It was early discovered, however, that these temperature sums varied greatly from one year to the next.

The first improvement in this method was the introduction of a "plant zero," or the consideration only of those temperature readings above a certain minimum, below which the plant made no progress in growth. The temperature most frequently considered as a plant temperature "zero" was 42°F, and this amount was subtracted from each daily temperature before determining the sums for the season. This method presumed, of course, that the effectiveness of temperature in promoting plant growth was directly proportional to the number of degrees above this minimum, no limit as to maximum being fixed.

#### *Faults of summation method.*

In order to demonstrate the futility of this method, which has been so extensively used and is still considered efficient by some, the splendid phenological records of Mr. Thomas Mikesell (5) and his temperature readings at Wauseon, Ohio, have been studied and tables compiled, using maize as a representative cereal crop and the peach as a fruit crop. In the case of maize, temperature summations were made for the period between planting and blossoming for 27 years, also from blossoming to ripening for the same years. Both sets of figures show wide variations from year to year, ranging from 1,232 in 1897 to 1,919 in 1895 for the earlier life phase. Even wider differences obtained in the later phase, the extremes being 897 in 1907 and 1,607 in 1906.

In the case of the peach five different periods were considered, using 27 years' records. The first period was from January 1 to blossoming each year; the second, from blossoming to ripening; the third, from January 1 to ripening; the fourth, from the date of blossoming one year to date of blossoming the next; and the last, from the date of ripening one year to the date of blossoming the next. Table 1 shows the extreme values in each period and the range of variation expressed in percentage of the smaller to the greater.

TABLE 1.—*The least and the greatest temperature summations in the life phase of the late Crawford Peach, as observed at Wauseon, Ohio, by T. Mikesell from 1883 to 1912.*

[The fourth line gives the corresponding percentage when maximum instead of mean daily temperatures are used.]

| Summation. | Jan. 1 to blossoming. | Blossoming to ripening. | Jan. 1 to ripening. | Blossoming to ripening. | Ripening to blossoming. | Average. |
|---|---|---|---|---|---|---|
| Least | 183 | 2,766 | 3,030 | 3,565 | 486 | ..... |
| Greatest | 362 | 3,991 | 4,347 | 4,947 | 1,250 | ..... |
| *Percentage* | *50* | *70* | *70* | *75* | *38* | *61* |
| **Max (%)** | **64** | **71** | **72** | **78** | **61** | **69** |

It is evident from these wide variations that the summation method of studying the temperature requirements of crops is not productive of consistent results.

The various summations noted above were made from the mean daily temperatures. Similar summations were also compiled from the maximum temperatures instead of the means, and considerably closer results were obtained. The resulting percentages corresponding are given in the last line of Table 1 in black-face type, and they attain an average of 69 per cent, compared to an average of 61 per cent with mean temperatures. These closer results may be explained by the well-known fact that two days may have the same mean temperature, but one is cloudy and cool throughout with no plant growth, while the other has a clear and cooler night with a clear but warmer daytime with considerable growth. The clear daytime would have the higher maximum temperature and the greater weight it would thus secure in the summation process would more correctly represent the value of this day to the plant.

If the summation methods are to be continued, therefore, it is recommended that maximum temperatures rather than the mean daily temperatures be used. But neither gives satisfactory results.

#### *The exponential method.*

As a modification of the summation method of studying the efficiency of air temperature in promoting plant growth, Lehenbauer (7), Livingston (8), and others have made use of Van't Hoff's law regarding chemical action as accelerated by increase of heat. They reasoned that as plant growth is largely chemical in nature, it should increase and double with each rise of 18 Fahrenheit degrees in temperature, as it does in purely chemical reactions. The fomula used is: $u=2^{\frac{t-42}{18}}$, where $u$ is the value to be found and $t$ is the temperature on the Fahrenheit scale.

$u$ is therefore the exponential function of the temperature itself, hence a temperature of 60° F. has a value of 2, 78° F. of 4, etc. Lehenbauer found, by actual tests on the growth of maize seedlings, that the growth rate at maintained temperatures followed Van't Hoff's rule, only for medium temperatures. It gives increasingly higher value, for higher temperatures and is therefore more accurate up to a certain limit, which is the temperature for the optimum growth rate, beyond which its values are much too high, because increase in temperature beyond the optimum means decreasing growth rate. This method fails, then, for one reason, as Zon (**9**) has pointed out in the case of the summation process, because it does not take account of this decrease in growth rate beyond the optimum temperature.

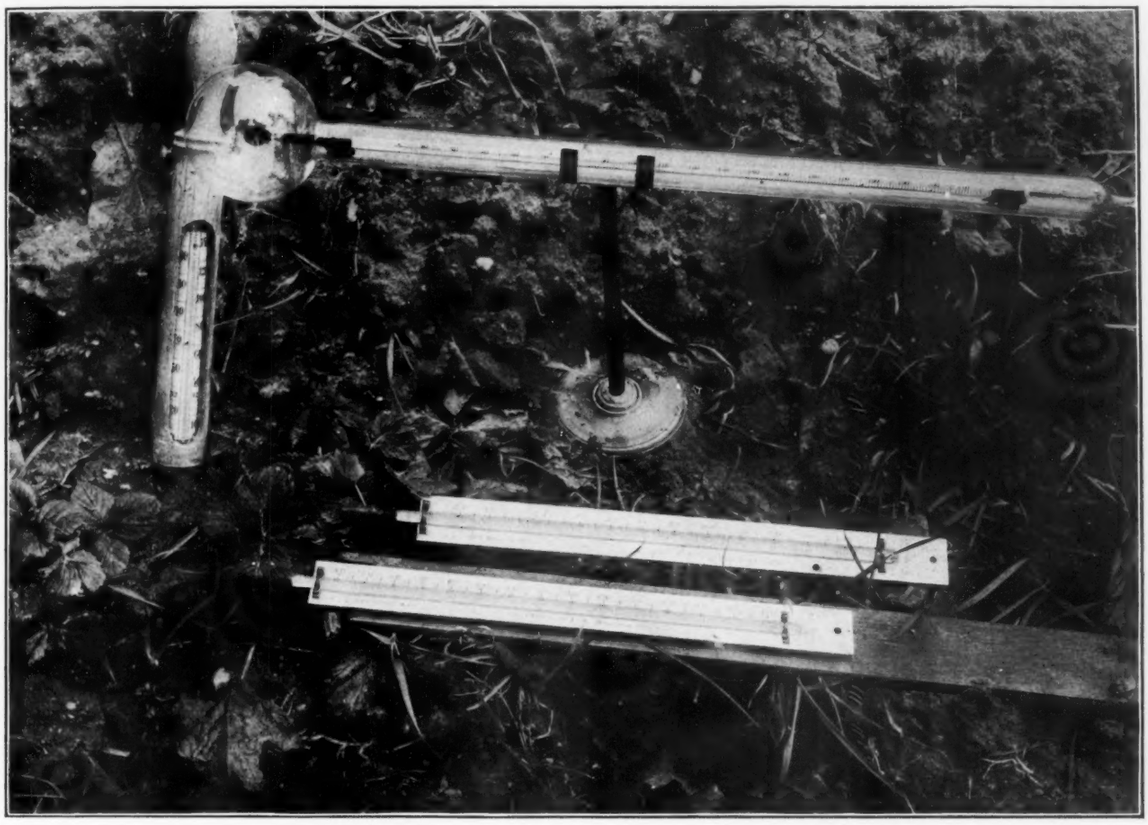

FIG. 1.—View of the exposures of thermometers furnishing the data for this study of plant and soil temperatures at the U. S. Weather Bureau station at East Lansing, Mich.

*The physiological index method.*

Realizing this fact Livingston (**10**) has worked out a series of indices of temperature efficiency for plant growth, based on Lehenbauer's measurements of growth of maize seedlings as influenced by temperature. He used the curve established by Lehenbauer and simply measured the rate of elongation at each temperature, using the elongation which took place at 40°F. as unity. At 89°, which was the optimum temperature for growth, the index was 122.3, after which it rapidly decreased to unity again at 116° F.

Livingston realized five imperfections in this method, viz: (1) It was established on a single plant species; (2) the seedling stage only was considered; (3) the shoot elongation was the only process of growth considered; (4) the environmental conditions were more limited than they are in nature; (5) measurements were made under maintained temperature conditions while in nature temperature conditions are exceedingly variable. He claims, however, that his method will be found to be an improvement over previous methods.

In order to test his assumption his indices were applied to the daily temperatures, both mean and maximum, during the two growth phases in maize at Wauseon, Ohio, previously mentioned, for the two years in which the extreme values were obtained by the summation process. It was believed that if the method had merit it would bring these extreme results nearer together. Table 2 shows the values obtained.

TABLE 2.—*Results obtained by the physiological index method of determining temperature efficiency, devised by Livingston, as compared with temperature summation results, during the two phases of growth in maize during years of extreme values as regards temperature requirements.*

| Phase of growth. | Year. | Summation method (mean above 43° F.). | Livingston method. | |
|---|---|---|---|---|
| | | | Mean temperature. | Maximum temperature. |
| Early growth phase (appearance above ground to blossoming) | 1895 | 1,919 | 4,234.0 | 5,962.0 |
| | 1897 | 1,232 | 2,796.4 | 4,373.8 |
| Relation of lower to higher in percentage | | 64 | 66 | 74 |
| Later growth phase (blossoming to ripening) | 1906 | 1,607 | 3,204.7 | 6,029.5 |
| | 1907 | 897 | 1,596.2 | 3,549.7 |
| Relation of lower to higher in percentage | | 56 | 50 | 59 |

While the Livingston method brought the thermal values slightly closer together in the case of the earlier life phase, there is an even greater difference in the results obtained in the two years during the later growth phase,

when mean daily temperatures are used, but a very small improvement when maximum readings are considered. The closer results obtained with the maximum temperature readings, instead of the means, amounted to 8 per cent and 9 per cent in the two phases, respectively, which supports the contention earlier made that maximum temperatures should be used. But even with these the results are not satisfactory with any system so far advanced.

*Plant temperature.*

The author believes that sufficient attention has not been given to the matter of temperatures of the growing plant in studies of the relationship between temperature and growth. The various parts of the living plant, by reason of their color and texture, have far different powers of absorbing and radiating insolation from those of the air which surrounds them. Many investigators have shown that leaf temperatures are higher when the sun is shining, than the surrounding air. Ehler (**12**) found that the temperature of pine leaves in bright sunshine, even in winter when insolation values are at their lowest, was 2 to 10 degrees C. ((3.6 to 18 degrees F.) higher than the surrounding air. Askenasy (**13**), Ursprung (**14**), Miss Matthaei (**15**), and Smith (**16**) have each found leaves of plants warmer than the air, the difference in temperature depending on the clearness of the sky, the season of the year, time of day, wind velocity, humidity, and possibly other factors, the difference amounting to as much as 40 degrees (F.) or more in some extreme cases.

During the past two years some observations have been made of the leaf temperature of the garden strawberry, *Fragaria vesca* growing on the Weather Bureau grounds at East Lansing, Mich. (lat. 42° 44′; long. 84° 26′; alt., 855 feet above sea level). These observations have been made in a rather crude way, by means of cylindrical-bulb minimum thermometers, as shown in the photograph herewith (fig. 1). The growing leaf was simply folded around the bulb and held in close contact with it by means of a pin or small splinter of wood. Care was taken to use a new leaf frequently. It is realized that this method did not give strictly accurate data as to the internal leaf temperature, and yet the results are believed to be but slightly in error compared to the very wide variations in temperature noted between the leaf and surrounding air temperatures. The difference between the readings of two thermometers similarly mounted to determine plant-leaf temperature was slight, never reaching 1 degree (F.), which would indicate that the readings obtained were approximately correct. Readings were made daily of the registered minimum temperature, and also the current temperature at 7 a. m., midday (regularly at 2 p. m. in 1916), and at 7 p. m. Alongside the plant-temperature thermometers a soil thermometer was exposed, with its bulb about 1 inch below the surface, and also a black-bulb in vacuo "solar radiation" thermometer. The two latter

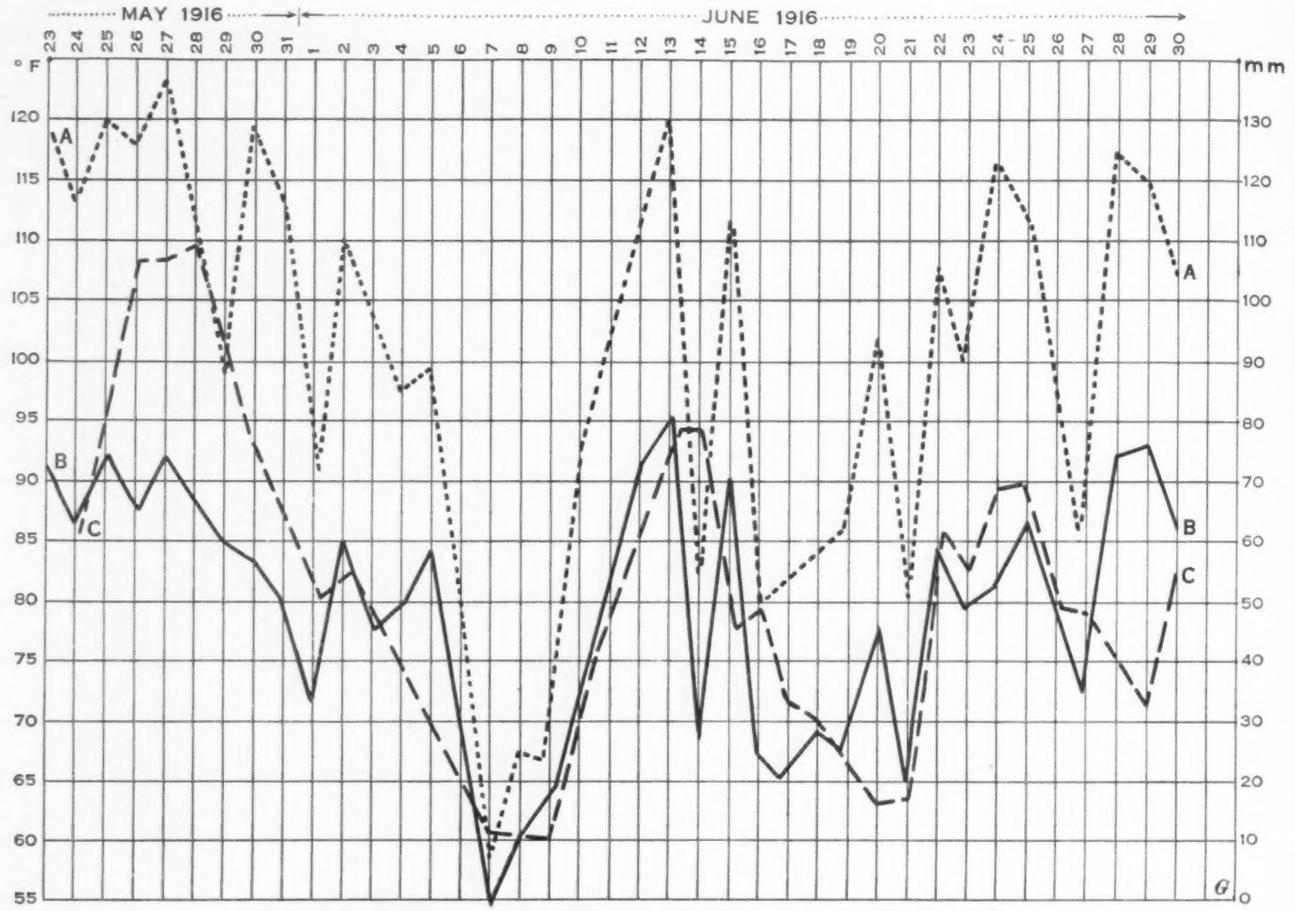


FIG. 2.—Curves of radiation, temperature, and plant growth at Weather Bureau office, East Lansing, Mich.
*A*= Daily readings of "solar radiation thermometer" (°F).
*B*= Midday readings of the plant thermometer (°F).
*C*= Daily elongation, in millimeters, of four plants; measurements made at 2 p. m.

thermometers were read thrice daily during the growing season of 1916 at the same hours as the plant thermometers.

For lack of space but one month's daily records are reproduced as Table 3 of the present paper, but it will serve to illustrate the characteristic variations in readings. The plant thermometer readings were usually lower than the air temperature in the early morning, the minimum usually being about 3 or 4 degrees (F.) lower than the air, the differences being greater, of course, when the weather was clear with but little wind velocity. The plant cooled off more rapidly than the air in the early evening, so that at 7 p. m. it was usually 3 or 4 degrees (F.) lower in temperature than the surrounding air. On very warm days, with clear skies and still air, differences as great as 9 or 10 degrees (F.) were observed. But the most striking difference made by placing a marked leaf against a stake which had been firmly driven into the ground alongside the plant at the beginning, and marking the height of the leaf tip on the stake daily at 2 p. m. The total daily elongation (in mm.) of the four plants was used in plotting the curve. The plants were kept well watered throughout the experiment. In connection with the curves of growth rate and plant temperature in figure 2, there is given curve *A* for the radiation thermometer. Figure 3 has, in connection with the same growth-rate curve, *C*, curves of soil temperature, *S*, and of the maximum and mean air temperatures (*Mx* and *m*). It will be noted that the parallelism between the plant temperature (*B* in fig. 2) and growth-rate curves is closer than that between any other temperature curve and that for growth rate.

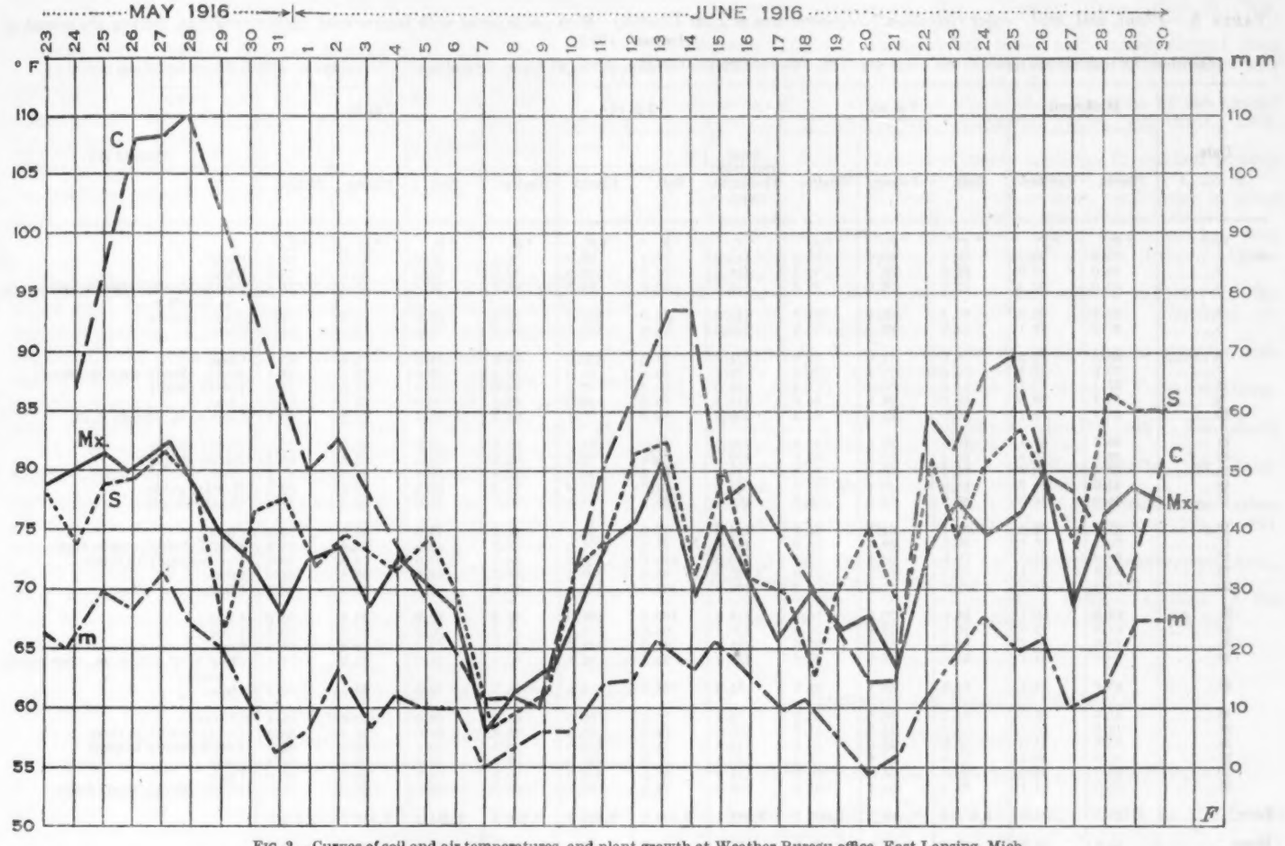


FIG. 3.—Curves of soil and air temperatures, and plant growth at Weather Bureau office, East Lansing, Mich.
*C*= Total daily elongation of four plants, measured at 2 p. m. (cf. fig. 2).
*Mx*= Maximum air temperature daily.
*m*= Mean daily air temperature.
*S*= Soil temperature, read at 2 p. m. daily.

between leaf and air temperature occurred during the heat of the day, when they frequently amounted to 20 degrees (F.), and on a few occasions reaching 36 degrees (F.). The plant was at the higher temperature at the midday observation on all but 41 out of the 304 days that readings were made. These 41 days were all dark and cloudy, many of them with rain falling at the time of observation.

The fact that there is a close relationship between growth rate and the temperature of the plant itself is clearly shown by curves of growth rate, *C*, and of plant temperature, *B*, reproduced in figure 2. The curve of growth rate (*C* in fig. 2) is based on plant elongation measurements made on four plants—two gladioli and two soy beans—growing near the point where temperature readings were taken. The measurements of growth were

The closer connection between the temperature of the plant itself and the rate of growth and development was demonstrated by another experiment conducted as follows: On April 6, 1916, before there were any visible signs of awakening in plant life out-of-doors, a cherry tree was removed from the college nursery to the botanical greenhouse. Thermograph records of temperature were obtained both out-of-doors and in the greenhouse until the blossoms opened. This event occurred in the greenhouse on April 19, thirteen days after removal from out-of-doors, while cherry trees of the same variety in the open air did not blossom until May 9, or twenty days later. From the temperature traces the total "temperature hours" was computed, indoors for the 13 days and out-of-doors for the 33 days, by giving to

each hour a value equal to its temperature minus 42°F. This gave 9,048 for the greenhouse and 4,228 for the open air. Evidently the air temperatures were not reliable sources from which to determine the amount of heat which was required to bring out the blossoms. A third temperature trace was constructed by interpolating from the four-daily plant temperature readings (minimum, $7^a$, $2^p$, and $7^p$) which was only roughly correct, but which gave a total of 7,877 by the same system. If the effect of transpiration is taken into account, one may safely assume that the shaded tree in the greenhouse was about 2.7 degrees (F.) cooler than the thermograph bulb, if we accept Darwin's (17) figures for the reduction due to transpiration. This would bring the thermal value in the greenhouse down to 8,237 as compared with 7,877 out-of-doors, which is remarkably close.

brightly, while the difference between plant and air temperatures is lessened in proportion to the density of cloudiness. The 304 observations of plant temperature at midday have been collected under three headings: (1) those taken in bright sunshine; (2) those with a partially obscured sun; and (3) those when the sky was thickly overcast. Out of a total of 115 observations in clear weather, the average excess of plant temperature over that of the air was 15.2 degrees (F.); 88 partly cloudy days showed an average of 9.7 degrees excess, while on 101 cloudy days the average excess of plant temperature was 0.9 degree. These all refer to midday observations.

With this as a basis the writer has evolved a formula for evaluating air temperature readings as to their efficiency in promoting plant growth. The formula makes use of these temperature excesses in clear, partly cloudy,

TABLE 3.—*Plant, soil, and "solar radiation" temperatures at East Lansing, Mich., compared with instrument shelter readings, during the month of August, 1916.*

[Location: All readings are taken on the south side of the Weather Bureau building on the Michigan Agricultural College campus, within fifteen feet of one another.]

| Date. | Minimum. | | 7 a. m. | | | 2 p. m. | | | | 7 p. m. | | | State of sky. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Plants. | Shelter. | Soil. | Plants. | Shelter. | Solar radiation thermometer. | Soil. | Plants. | Shelter. | Soil. | Plants. | Shelter. | |
| 1916. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | °F. | |
| Aug. 1 | 55.9 | 59.2 | 70.0 | 60.0 | 63.0 | 118.0 | 96.0 | 92.0 | 81.2 | 80.0 | 61.0 | 69.0 | Clear. |
| 2 | 46.0 | 49.0 | 65.8 | 55.8 | 60.1 | 124.0 | 94.0 | 100.0 | 85.0 | 83.0 | 67.5 | 76.0 | Clear. |
| 3 | 58.0 | 62.5 | 72.0 | 67.0 | 69.5 | 101.0 | 87.0 | 85.5 | 86.3 | 78.0 | 66.0 | 71.2 | Partly cloudy; light sprinkle 1:20 p. to 1:30 p. |
| 4 | 59.5 | 64.0 | 69.5 | 66.1 | 71.3 | 125.0 | 94.0 | 104.0 | 92.5 | 82.0 | 74.0 | 79.5 | Partly cloudy. |
| 5 | 67.9 | 70.1 | 74.0 | 69.0 | 71.2 | 128.0 | 94.0 | 107.0 | 89.0 | 82.0 | 74.0 | 80.2 | Clear. |
| 6 | 68.5 | 72.2 | 76.0 | 74.0 | 78.0 | 124.0 | 94.0 | 100.0 | 94.3 | 84.0 | 77.0 | 85.8 | Clear. |
| 7 | 70.9 | 75.1 | 76.5 | 75.1 | 79.1 | 98.5 | 92.0 | 84.0 | 89.0 | 82.0 | 76.0 | 82.2 | Partly cloudy with showers. |
| 8 | 67.1 | 70.1 | 74.0 | 70.0 | 71.5 | 128.0 | 88.0 | 97.0 | 83.0 | 78.0 | 66.0 | 74.0 | Partly cloudy. |
| 9 | 55.1 | 59.0 | 68.0 | 61.8 | 64.6 | 118.5 | 86.0 | 96.0 | 82.0 | 76.0 | 63.7 | 70.0 | Clear. |
| 10 | 56.1 | 59.1 | 66.0 | 61.0 | 65.2 | 109.8 | 82.0 | 86.1 | 84.0 | 76.0 | 74.2 | 80.3 | Clear a. m.; cloudy p. m. |
| 11 | 66.8 | 69.1 | 73.5 | 70.2 | 72.8 | 109.0 | 83.0 | 91.0 | 82.0 | 76.0 | 68.5 | 75.0 | Partly cloudy. |
| 12 | 52.2 | 55.0 | 64.5 | 57.4 | 62.0 | 122.0 | 84.0 | 92.0 | 82.0 | 70.0 | 63.5 | 69.2 | Partly cloudy. |
| 13 | 49.0 | 50.9 | 61.5 | 52.0 | 54.9 | 118.5 | 82.0 | 83.0 | 71.8 | 70.0 | 54.0 | 61.1 | Clear. |
| 14 | 43.9 | 44.6 | 58.0 | 49.1 | 53.9 | 88.5 | 74.0 | 73.0 | 71.0 | 68.0 | 57.0 | 62.0 | Mostly cloudy. |
| 15 | 45.0 | 48.3 | 58.5 | 52.6 | 56.0 | 102.0 | 82.0 | 83.0 | 80.0 | 73.0 | 65.0 | 71.0 | Mostly cloudy. |
| 16 | 57.9 | 62.0 | 67.5 | 64.1 | 65.1 | 120.0 | 92.0 | 98.0 | 84.5 | 79.0 | 69.0 | 74.3 | Clear. |
| 17 | 56.8 | 59.8 | 66.5 | 62.0 | 64.0 | 121.0 | 91.0 | 96.0 | 88.2 | 78.0 | 64.0 | 73.3 | Partly cloudy, clouds thin. |
| 18 | 60.0 | 64.7 | 70.0 | 68.1 | 72.3 | 116.0 | 88.0 | 100.0 | 88.0 | 83.0 | 72.0 | 78.0 | Partly cloudy to cloudy. |
| 19 | 67.0 | 70.1 | 72.5 | 72.3 | 75.0 | 120.0 | 93.0 | 103.0 | 95.7 | 84.0 | 75.0 | 84.0 | Clear. |
| 20 | 65.2 | 68.1 | 72.0 | 70.0 | 73.1 | 136.0 | 100.0 | 113.0 | 98.2 | 82.5 | 75.5 | 83.7 | Clear. |
| 21 | 65.0 | 68.1 | 74.0 | 70.9 | 74.0 | 113.5 | 100.0 | 108.0 | 96.2 | 86.0 | 75.5 | 84.0 | Clear. |
| 22 | 68.6 | 73.8 | 76.0 | 72.8 | 76.5 | 129.5 | 96.0 | 104.0 | 87.2 | 80.0 | 64.0 | 69.3 | Clear. |
| 23 | 48.9 | 52.2 | 64.0 | 53.0 | 57.0 | 124.0 | 91.0 | 103.1 | 78.0 | 76.0 | 59.0 | 68.0 | Clear. |
| 24 | 48.9 | 54.1 | 64.0 | 56.0 | 61.0 | 127.8 | 90.5 | 97.8 | 86.0 | 78.0 | 65.5 | 74.0 | Clear until 4:30 p. m., then partly cloudy. |
| 25 | 48.9 | 52.1 | 62.0 | 53.1 | 57.0 | 94.0 | 86.0 | 85.0 | 78.7 | 73.0 | 69.5 | 66.2 | Clear. |
| 26 | 51.9 | 56.0 | 64.3 | 58.0 | 60.2 | 70.0 | 70.0 | 66.0 | 65.0 | 68.0 | 60.0 | 62.1 | Cloudy. |
| 27 | 43.6 | 46.7 | 58.0 | 48.0 | 51.7 | 108.0 | 72.0 | 86.0 | 71.0 | 68.0 | 54.0 | 60.0 | Partly cloudy to clear. |
| 28 | 38.9 | 41.0 | 56.0 | 45.0 | 48.0 | 118.0 | 74.0 | 103.0 | 75.0 | 70.0 | 55.0 | 62.5 | Partly cloudy to clear. |
| 29 | 46.0 | 49.4 | 59.0 | 53.1 | 57.0 | 110.5 | 77.0 | 92.0 | 79.0 | 72.0 | 59.0 | 65.8 | Clear. |
| 30 | 49.0 | 54.5 | 62.0 | 56.5 | 60.9 | 118.0 | 80.0 | 102.0 | 80.1 | 72.0 | 58.0 | 67.0 | Clear. |
| 31 | 50.0 | 54.1 | 62.0 | 58.1 | 62.0 | 103.0 | 78.0 | 87.8 | 83.0 | 74.0 | 64.5 | 73.1 | Partly cloudy, thin clouds. |
| Sum | 1,728.5 | 1,834.9 | 2,077.6 | 1,902.1 | 2,007.9 | 3,564.1 | 2,690.5 | 2,918.3 | 2,586.9 | 2,381.5 | 2,046.9 | 2,251.8 | |
| Mean | 55.8 | 59.2 | 67.0 | 61.4 | 64.8 | 115.0 | 86.9 | 94.1 | 83.4 | 76.8 | 66.0 | 72.6 | |

It is a fact that the higher temperature produced by sunshine is only one factor in promoting plant growth, as the actinic action of sunlight plays an important part in the metabolic processes going on within the plant. Whether the increase in temperature can be taken as a measure of the increased effectiveness of sunshine in this second influence is problematical, and needs investigation.

*A working formula.*

A study of the readings which have been made at East Lansing, shows that sunshine is a controlling factor in determining plant temperature, and furthermore that plant temperature largely determines the rate of plant growth and development. Cloudiness thus enters into the problem in that it lessens sunshine. The plant is much warmer than the air when the sun is shining and cloudy weather, which in round numbers are 15, 10, and 1 degree, respectively; but the last amount has been disregarded as being too small to materially affect the results obtained through a formula which is considered still rather crude. If we indicate by

$X$, the number of days having a maximum temperature above 42°F.;
$m$, the sum of all maximum temperatures above 42° during the period $X$;
$C$, the number of clear days during this period;
$P$, the number of partly cloudy days during this period;
$T$, the effective temperature-total sought;

and let

$$t = m - 42X,$$

then we may write our formula

$$T = t + 15C + 10P.$$

Although recognizedly imperfect and held subject to amendment after further investigations, this formula will be found to bring about much closer results than the simple summation method or any other modifications of it so far advanced.

The final formula which is to be brought out with further study, will take into consideration more accurate values for plant temperature, and give proper weight to the effect of wind velocity, humidity, and both the caloric and actinic value of sunshine.

In conclusion it should be stated that these studies are only preliminary to others which the author hopes to make with the aid of more accurate instruments and methods. It is realized that an enormous amount of research must be carried through before the final goal is reached and an exact formula established for expressing the complete relationship between climatic or weather conditions and crop production; and that this is only a minute contribution toward the desired end.

The valuable suggestions and assistance rendered by Drs. E. A. Bessey and R. P. Hibbard, by Profs. A. R. Sawyer, C. W. Chapman, and others of the Michigan Agricultural College, are gratefully acknowledged, as is also the assistance given by Mr. B. B. Whittier, observer, in making many thermometric readings.

## SUMMARY.

The relation between weather and crop production is vital and important, but definite statements as to the exact relationships existing are lacking, for the most part, especially in regard to the rôle of temperature. In the latter respect we need a statement of the plant's thermal requirements and a method of evaluating air temperature in terms of its efficiency to meet these requirements.

The method most generally used has been called the summation process, consisting of simply adding together the mean daily air temperatures during the life phase of a crop, in order to find the thermal requirement. This produces widely differing results from year to year. The same process yields somewhat more consistent results if one employs maximum instead of mean temperatures; but the summation process is ineffective.

Van't Hoff's law, when introduced into the study by the exponential method, also fails to produce consistent results, mainly because it does not take into account the optimum temperature for growth.

Livingston's "physiological index" method of evaluating temperatures is based on a reasonable footing in that he used actual growth rates resulting from differing temperatures; but it does not produce much closer results when it is actually applied to the problem.

It is believed that the temperature of the plant itself should be given more consideration, as it is much warmer than the air when bathed in sunshine. Observations carried on at East Lansing during 1915 and 1916 show that this excess in temperature of the plant over the air in clear weather averages about 15 degrees, in partly cloudy weather 10 degrees, and in cloudy weather less than 1 degree (F.). Curves expressing plant growth rates and plant temperatures show parallelisms more decided than other temperatures observed, including maximum and mean air temperatures, soil temperatures, and readings of the "black-bulb in vacuo." A test of the number of heat units required to cause a cherry tree to blossom in the greenhouse and out-of-doors shows remarkably close results when plant temperatures are considered, but a consideration of air temperatures alone gives a wide variation.

A formula is evolved for determining the effectiveness of air temperature in promoting crop development, as follows: $T=t+15C+10P$, $t$ being the sum of maximum temperatures above 42° during a certain period, after that amount has been subtracted from each temperature, $C$ being the number of clear and $P$ the number of partly cloudy days during the period.

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## DAMAGE BY HAIL IN KANSAS.

By S. D. FLORA and C. L. BUSH.

[Dated: Weather Bureau Office, Topeka, Kans., Apr. 17, 1917.]

In Kansas damage by hail is most serious in the fields of growing wheat, and in the wheat-growing belt of the United States it is a widespread practice to insure against such loss by hail. It therefore seemed reasonable, to the writers, to expect to find that in this wheat belt there had been made a close study of the occurrence of hail. So far as they have been able to ascertain, however, no systematic collection of data relative to hailstorms in Kansas—the greatest wheat-growing State of the Union—has ever been attempted beyond the statistics of losses sustained there by the companies issuing hail insurance. This omission seems all the more striking in view of the fact that reliable estimates indicate hail-caused damage amounted to more than $6,000,000 during 1915 alone—an amount of damage many times greater than ever resulted from the tornadoes of any single year and probably greater than the average annual damage from unseasonable frosts. Yet both tornado and frost occurrences have been studied at length.

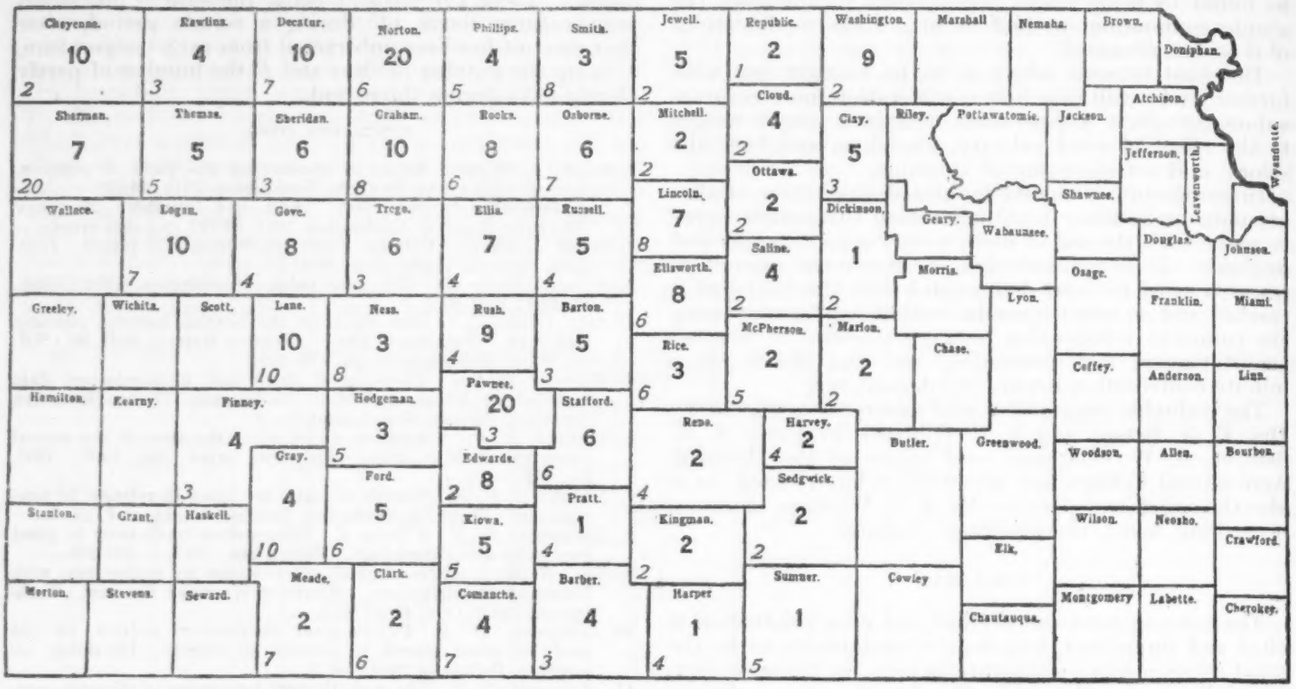


FIG. 1.—Percentage of wheat crop in Kansas damaged by hail during the past 18 years (by counties) as inferred from the records of the most important hail-insurance company of that State. Figures in italics give the percentage of the wheat crop of each county that was insured in this company.

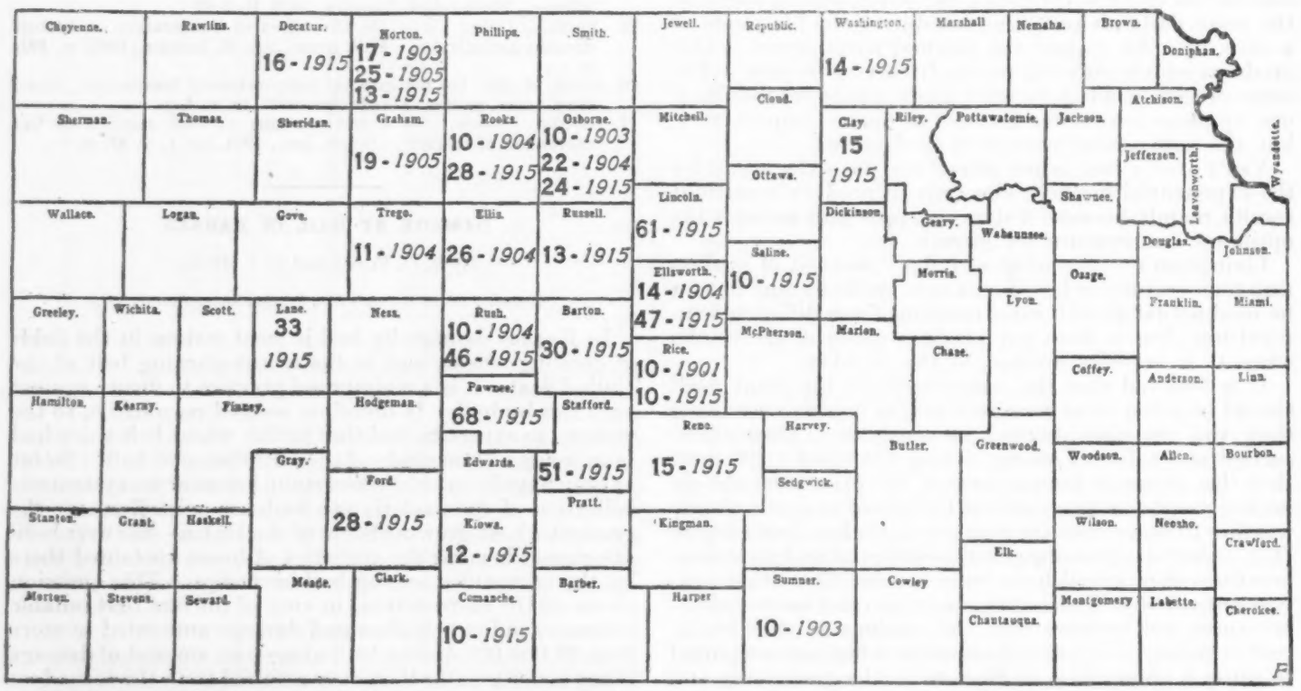


FIG. 2.—Heaviest losses due to hail (expressed in thousands of dollars) sustained in different Kansas counties by the hail-insurance company of fig. 1.

Practically the only record of loss due to hailstorms is that kept by the hail-insurance companies in their efforts to fix equitable rates for the different counties, and of these the records of but one company cover the State sufficiently and extend over a long enough period of time to give a reliable index of the probability of the occurrence of hail. This company has written almost as much hail insurance in Kansas as all other companies combined, its records showing that it has insured an average of approximately 3½ per cent of the total wheat crop of the State for the past 14 years. A study of its losses, which have been carefully compiled, should give an important clue to the distribution of the loss over the State from year to year.

The average annual loss by hail to the wheat crop in the principal wheat-growing counties of Kansas, expressed as a percentage, is shown in convenient summary in figure 1. The percentages there printed were obtained as follows: The total wheat acreage for each county was taken from the reports of the Kansas State Board of Agriculture. The total acreage insured in each county by the insurance company before mentioned, and the total loss sustained each year in each county by that company, were obtained from the latter. From these figures it was simple to compute the percentage of the total risk lost each year during the period of 18 years, 1899 to 1916, inclusive. Strictly speaking, the figures on the chart, figure 1, are the percentages of loss sustained by the *insured* crop, but it seems safe to assume that, without reasonable error, hail damage was uniform throughout the county, and therefore we present the figures as representing the best obtainable evidence of the damage due to hail in each county. Data for the less important wheat-raising counties have been omitted since the business done by the company there has hardly been sufficient to give a reliable average.

It is interesting to note that the percentage of damage in the extreme eastern counties for which data are available, is considerably less than that of the western. In fact the rate charged by this company for the western counties, as deduced from its tables of loss, is two and a half times that charged for the eastern, and the records of the company show it has lost money on its business done in the western counties while the business done in the eastern counties at the lower rate has paid good dividends.

Figure 2 shows all losses of $10,000 or more sustained by this company on account of individual storms, and serves to explain the abnormally heavy percentage of loss shown in figure 1 for a few counties such as Norton and Pawnee. The fact that most of these heavy individual losses have occurred in the central counties instead of the western, where the average for the entire period is highest, may be due partly to the heavier stands of wheat in the central portion of the State and partly to more frequent and less violent hail storms in the western portion. There are very few data, however, to support the latter contention.

Hail is so commonly associated with thunderstorms and thunderstorms with heavy rainfall, that it is somewhat difficult to understand why the probability of damage by hail increases toward the western portion of Kansas when both the average annual rainfall, and the rainfall for the crop-growing months in the western third of the State are less than half the averages for those periods in the eastern third. This anomaly is emphasized by Table 1.

TABLE 1.—*Losses sustained by hail insurance company in Kansas compared with departures of the July–August rainfall, 1899 to 1916, inclusive, for the State.*

| Year. | Percentage of loss sustained by hail insurance company. | Departure from normal of total rainfall for July and August. |
|---|---|---|
| | *Per cent.* | *Inches.* |
| 1899 | 1 | +0.55 |
| 1900 | 2 | −1.06 |
| 1901 | 2 | −2.27 |
| 1902 | 3 | +2.44 |
| 1903 | 4 | +1.59 |
| 1904 | 7 | +2.99 |
| 1905 | 9 | +2.99 |
| 1906 | 2 | +1.86 |
| 1907 | 5 | +0.27 |
| 1908 | 6 | +0.70 |
| 1909 | 5 | +0.34 |
| 1910 | 1 | −0.21 |
| 1911 | 4 | +0.99 |
| 1912 | 2 | −0.01 |
| 1913 | 3 | −4.94 |
| 1914 | 1 | −0.77 |
| 1915 | 9 | +3.90 |
| 1916 | 5 | −1.96 |

While this table indicates that the damage by hail is not always proportional to the amount of rain that falls during the harvest months, July and August, the losses of dry seasons such as occurred in 1901, 1910, and 1913, have been small, while those of the notably wet harvest seasons 1904 and 1915 have been heavy; in fact, the season of 1915 brought failure to more hail insurance companies doing business in Kansas than any other year in the history of the State.

What causes this increase in liability of damage by hailstorms in the drier western counties of Kansas? This is an interesting problem that is worthy of future investigation.

## SCARF CLOUDS.

By CHARLES F. BROOKS, Ph. D.

[Office of Farm Management, Washington, July 25, 1917.]

(These notes were written immediately after the observations were made, and before having read anything on the phenomena. Therefore, my observations only substantiate the conclusions reached by previous writers mentioned in the footnotes.)—C. F. B.

The name "scarf cloud" has been applied in conversation, by Prof. W. J. Humphreys to a cloud which forms immediately over a rapidly rising cumulus dome and through which the rising cloud passes without hesitation.

On July 13, 1917, at Washington, D. C., the light easterly wind, clear air, and moderate humidity favored the growth of towering cumuli. By noon some had attained their limiting height, and were sending false cirrus sheets eastward. At about 4 p. m. some showers of very large drops bore witness to the rapidity of the ascending currents through which they fell. By 6 p. m. the air stratum where the cumulus clouds had been spreading their tops was well supplied with moisture, a fact which was marked by the scattered dissolving cirrus cirro-stratus, and cirro-cumulus clouds at this level.[1] At 6:22 a towering ebullient cloud in the north was seen to be surmounted by a thin "disk-cloud";[2] at 6:23 the

[1] Compare *W. J. Humphreys* in Bull., Mount Weather obs'y, Washington, 1909, 2:133–135. The "cirro-stratus" of the International cloud atlas, 1896, Pl. xii, fig. 23.

[2] This "disk cloud" is clearly the same as the usual "cap cloud" or "cumulus cap" whose origin was explained by C. Abbe in this REVIEW, October, 1906, 34:457, and yet earlier described and explained, among others, by Groneman in Meteorol. Ztschr., April, 1901, 18:176–177; Luke Howard, Essay etc., p. 5 & 10.—EDITOR.

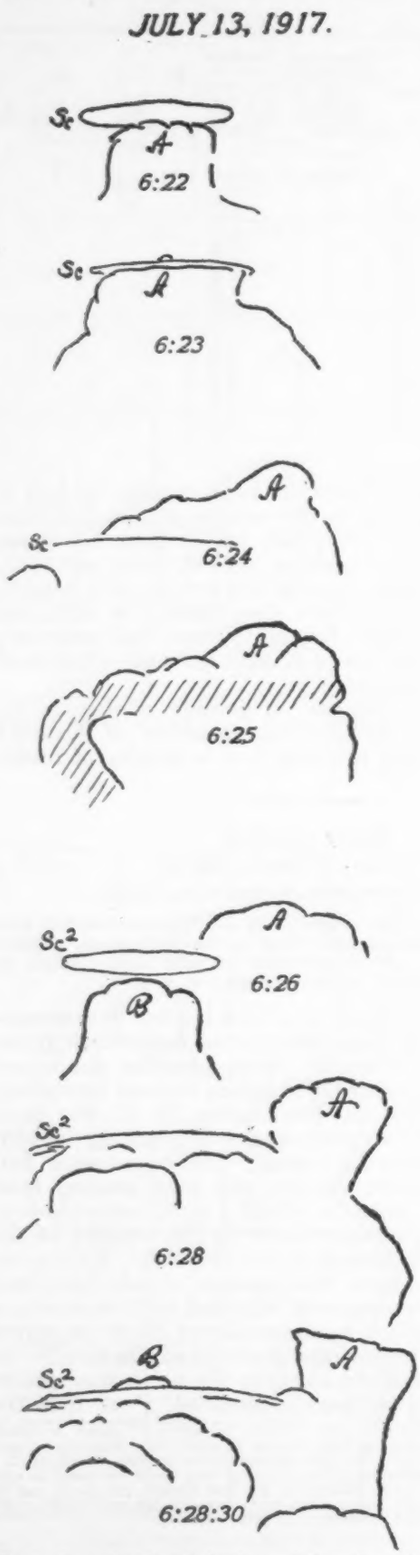


FIG. 1.—Successive stages in development of cumulus with "scarf clouds," July 13, 1917.

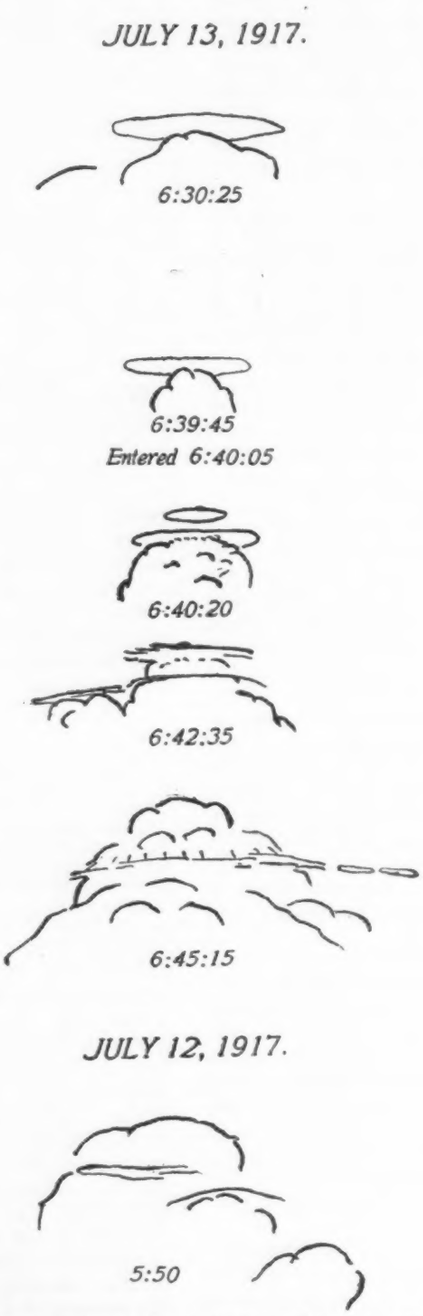


FIG. 2.—Successive stages in development of cumulus with "scarf clouds" July 13, 1917.

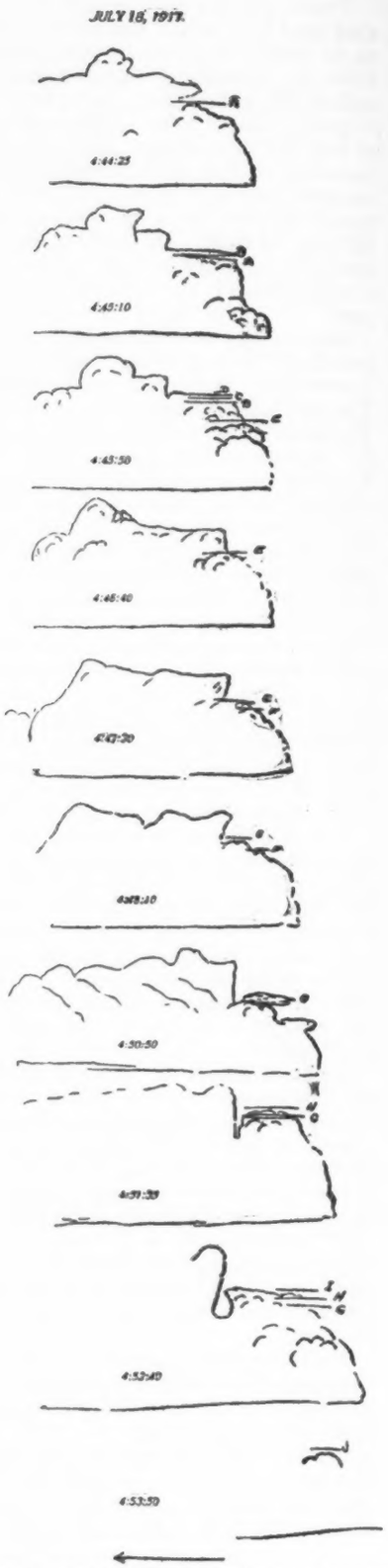


FIG. 3.—Successive stages in development of cumulus with "scarf clouds," July 18, 1917.
(Arrow shows drift of cumuli.)

cumulus head appeared above the scarf, and at 6:24 but little of the scarf remained (Fig. 1). At this level was a band of shadow marking the level of the false cirrus clouds not far west. The sun being near the horizon, this shadow was like a narrow girdle round the cloud. At about 6:26 another cumulus head beside the large one made a scarf cloud, and at 6:28:30 it appeared above the top of the scarf. Another hump of the same cloud mass grew rapidly upward from the shadowy lower levels. I watched the air above the tip. At 6:30:25 the scarf cloud suddenly appeared above the rising column (Fig. 2); 30 seconds later the cumulus entered it, and in 55 seconds more it appeared over the top. At 6:32:40 the scarf was entirely gone. Sometime between 6:39:15 and 45 a scarf appeared over another cloud head; at 6:40:5 the cumulus entered the scarf. At 6:40:20 a second scarf cloud appeared above the first. Then at 6:41:30 the cumulus overtopped the first scarf, and at 6:42:35 the second. At the same time a secondary head rising toward the humid layer caused a fine three-leaved scarf cloud to form. By 6:43 the scarf clouds had disappeared. A minute later a thin sheet of cirro-cumulus was seen approaching the thunderhead; at 6:45:15 it reached the rising cloud and was there thickened into scarf formation. A scarf cloud was seen also on July 12, at 55:5 p. m., and another on July 14, at 6 p. m., on the rear side of a great cumulo-nimbus.

On July 18, from a train window between Trenton and New Brunswick, N. J., I observed in the southeast a series of ten scarf clouds between 4:44 and 4:54 on the rear of one cumulus cloud. The surface wind was a moderate breeze from the southwest; at the level of the base of the cumulus the movement was at about 40 kilometers per hour; while at the middle level, the movement was near 55 kilometers per hour, from the southwest. These velocity observations were taken on an accelerating train by noting the speed at which the clouds stopped their apparent forward motion and began to go backward. The train was running parallel to the cloud movement. The sheet of cirro-cumulus, alto-cumulus, and alto-stratus some distance above, was moving at a rate of less than 80 kilometers an hour toward the northeast. Above this false cirrus (?) sheet were some cirrus clouds with scarcely any perceptible forward motion. The level of maximum velocity within the cumulus layer seems to have been at about the middle of the cloud; and it was at this level that the scarf clouds formed. Above this height the top of the cloud seemed to have a dissolving tendency, and to move backward relative to the middle. Still higher, another stronger current from the west marked the top of the cloud; its presence was indicated by the apparent eastward lean of some projecting portions of the cloud. The total vertical thickness of the large cumulus probably did not exceed 2 or 3 kilometers. The ten sketches (Fig. 3) show how the scarf clouds formed successively as cumulus growths added themselves to the rear of the cloud. At 5:05 a small scarf cloud was seen just over one of the highest of the cumulus domes.

### *Conclusions.*

These observations lead to three conclusions:

1. One reason why the scarf cloud is infrequently observed is the rapidity of its formation and disappearance. The total duration of each of the six scarf clouds observed July 13, between 6:22 and 6:43, was from two to three minutes only, and those of July 18, from one to two minutes each. Furthermore, only in the late afternoon do conditions seem to favor their formation.

2. The rapidly rising column of saturated air in a cumulus cloud *apparently* elevated the superincumbent layers. The time interval between the appearance of the scarf and the entrance of the cumulus cloud into it gives some measure of the distance to which this raising is effective. And the time the cumulus top takes in going through the cap gives a rough measure of the thickness of the humid layer. The apparent rising motion of the cumulus towers indicates an ascending current, say, of 7 meters per second (a value which the writer once determined instrumentally at Blue Hill Observatory). With the average interval of 30 seconds from the time of appearance of the scarf to the entry of the cloud, the distance may be 200 meters. The thickness of the scarf is less than 400 meters, probably less than half this, for the scarf is raised with the cloud, and also the cloud comes through before it becomes visible below. The diameter of the scarf may easily be 1 kilometer, yet it formed almost instantly.

3. The top of the cumulus cloud actually does not move forward as fast as the flat clouds at the same level. This is to be seen when the false cirrus advances 50 or 100 kilometers before the oncoming thunderstorm; but rarely do we see a flat cloud overtake and surround the cumulus dome. Such was the case July 13; the great cumulus cloud, like a mountain, interrupts the free flow of the wind. Perhaps these scarf clouds like the helm clouds of mountains are formed by the winds rising to pass over the dome, rather than by the up-push of the rising cloud column.[3]

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## SOME FIELD EXPERIMENTS ON EVAPORATION FROM SNOW SURFACES.

By F. S. BAKER, Forest Examiner.

[Utah Experiment Station, Ephraim, Utah, June 25, 1917.]

In the irrigated section of the Great Basin of the western United States, one of the chief factors affecting crop production is the amount of snowfall in the adjacent mountains, as melting snows give rise to most of the irrigation water. So important are these snows that annual surveys are made on some of the more important watersheds in order to forecast, in a general way, the amount of run-off likely to be available. In other places windbreaks have been built in attempts to divert the drifting snow to certain watersheds. The amount of snow that will be effective in yielding water for use in the valleys is therefore of considerable importance throughout this entire region. In making snow surveys it has, of course, been recognized that much of the snow water is lost to surface run-off by evaporation and by percolation into the soil, but the magnitude of these losses has bever been determined.

At the Utah Forest Experiment Station, located on the Manti National Forest in the mountains of central Utah, an experiment is under way dealing with the effects of grazing on the erosion of the high mountain ranges. Two small drainage areas have been selected and equipped with sediment basins and weirs at their lower ends to determine the run-off and amounts of sediment that come from these areas during rains and seasons of melting snow. One area is to be grazed while the other is to be revegetated. One of the effects of revegetation will probably be to increase the percolation of snow water into the ground. This loss can not be directly determined, however, but as the amount of water on the areas in the form of snow is determined by surveys and the amount of run-off is obtained from weir readings, the water lost

[3] See *Max Reinganum* in Meteorol. Ztschr., Mai 1912, 29:242–3.

through percolation and evaporation together can be determined by subtracting the run-off from the water equivalent of the snow. Of this amount the quantity percolating into the soil could be indirectly determined if the evaporation were known.

An investigation of the amount of evaporation from snow surfaces was therefore undertaken at the Utah Experiment Station in the winter of 1915–16. In this study the evaporation was measured by the periodic weighing of a "hyaline" glass battery jar filled with snow. The jar was cylindrical with an inside diameter of 16 cm. and a depth of approximately 25 cm. The walls were of heavy glass approximately 5 mm. thick, but clear and only slightly tinged with green. This type of jar was used on account of its nonabsorption of heat and poor conductivity, as in even the best substitute, white enameled pans, the snow melts considerably on days when the [air] temperature never exceeds 32° F. The jar was filled with snow and then sunk in the open until its top was flush with the general level of the snow surface. It was removed and weighed daily at 8:30 a. m. and 4:30 p. m., so that the diurnal and nocturnal evaporation was determined separately. The weight was determined on balances sensitive to 1 gm., which was equivalent to a depth of 0.002 inch of water in the jar. The jar was refilled whenever the snow had fallen appreciably below the rim, care being taken to have surface snow always on the top. The jar was exposed in a flat clearing of about 5 acres in the aspen (*Populus tremuloides*) timber in which the experiment station is located and within the inclosure in which the meteorological instruments are exposed, open to the sun during the entire day.

The meteorological data used in the evaporation studies were gathered in connection with the regular work of the experiment station, it being a Weather Bureau cooperative station. Air temperatures were taken from a thermograph checked by Weather Bureau maximum and minimum thermometers exposed in a standard instrument shelter about 10 feet from the jar, the mean being taken from hourly readings.

Mean wind velocity was taken from the triple register records, the anemometer being located on top of the laboratory building 75 feet distant [and — feet above ground]. Humidity was determined daily at 8:30 a. m. and 4:30 p. m. with a standard Weather Bureau sling psychrometer.

The observations on evaporation, air temperature, and wind velocity are shown in detail in Table 1. Naturally no data could be obtained on days when snows occurred nor usually directly after storms when the wind was strong enough either to blow the light snow off or drift it over the battery jar. In the latter part of February the work had to be discontinued, as the water from the melting snow would freeze at night and break the jars. Therefore no data were obtained for evaporation during storm periods, high winds, or the spring thaw, but those obtained fully cover the calm, clear days of winter. Observations began November 11, 1915, and continued until December 9 with three interruptions due to storms. The latter part of December and all of January were very stormy and observations were not resumed until February 14, 1916, after which they were continued to February 25. Snow lay on the ground at the Utah Experiment Station from November 7, 1915, to May 4, 1916, a period of almost six months.

The mean diurnal and nocturnal evaporation from the snow surface, together with the mean temperature and wind velocity for the same period, are shown graphically in figure 1. Evaporation can not be strictly correlated

TABLE 1.—*Observations on snow evaporation, air temperature, and wind velocity at Utah Forest Experiment Station, Manti National Forest.*

| Date. | Time of observation (*) | Weight of jar. | Loss in weight. | Loss in depth. | Loss per hour. | Mean temperature. | Mean wind velocity. |
|---|---|---|---|---|---|---|---|
| 1915. | | *Grams.* | *Grams.* | *Thousandths of inch.* | *Thousandths of inch.* | °F. | *Mls./hr.* |
| Nov. 11 | A. M. | 2,487 | | | | | |
| | P. M. | 2,482 | 5 | 10 | 1.25 | 17.8 | 3.9 |
| 12 | A. M. | 2,481 | 1 | 2 | 0.12 | 13.8 | 5.0 |
| | P. M. | 2,473 | 8 | 16 | 2.00 | 24.8 | 13.4 |
| 13 | A. M. | (1) | | | | | |
| | P. M. | (1) | | | | | |
| 14 | A. M. | 2,493 | (2) | | | | |
| | P. M. | 2,489 | 4 | 8 | 1.00 | 20.9 | 2.2 |
| | | 2,496 | (2) | | | | |
| 15 | A. M. | 2,500 | −4 | −8 | −0.50 | 15.0 | 3.9 |
| | P. M. | 2,497 | 3 | 6 | 0.75 | 27.8 | 2.3 |
| 16 | A. M. | (1) | | | | | |
| | P. M. | 2,500 | (2) | | | | |
| 17 | A. M. | 2,508 | −8 | −16 | 1.00 | 9.4 | 4.1 |
| | P. M. | 2,507 | 1 | 2 | 0.25 | 16.5 | 2.9 |
| 18 | A. M. | 2,504 | 3 | 6 | 0.37 | 22.0 | 2.7 |
| | P. M. | 2,504 | 0 | 0 | 0.00 | 31.7 | 4.0 |
| 19 | A. M. | 2,510 | −6 | −12 | −0.75 | 24.1 | 3.4 |
| | P. M. | 2,505 | 5 | 10 | 1.25 | 38.4 | 2.7 |
| 20 | A. M. | 2,491 | 14 | 28 | 1.75 | 38.1 | 6.0 |
| | P. M. | 2,486 | 5 | 10 | 1.25 | 39.0 | 7.4 |
| | | 2,601 | (2) | | | | |
| 21 | A. M. | 2,597 | 4 | 8 | 0.50 | 34.5 | 3.9 |
| | P. M. | 2,587 | 10 | 20 | 2.50 | 42.7 | 6.9 |
| | | 2,648 | (2) | | | | |
| 22 | A. M. | 2,640 | 8 | 16 | 1.00 | 38.0 | 3.7 |
| | P. M. | 2,634 | 6 | 12 | 1.50 | 37.5 | 4.2 |
| 23 | A. M. | 2,629 | 5 | 10 | 0.62 | 33.9 | 3.5 |
| | P. M. | 2,616 | 13 | 26 | 3.25 | 47.4 | 5.9 |
| | | 2,775 | (2) | | | | |
| 24 | A. M. | 2,760 | 15 | 30 | 1.87 | 33.4 | 7.4 |
| | P. M. | (1) | | | | | |
| 25 | A. M. | 2,269 | (2) | | | | |
| | P. M. | 2,267 | 2 | 4 | 0.50 | 14.0 | 2.6 |
| 26 | A. M. | (1) | | | | | |
| | P. M. | (1) | | | | | |
| 27 | A. M. | (1) | | | | | |
| | P. M. | (1) | | | | | |
| 28 | A. M. | 2,401 | (2) | | | | |
| | P. M. | 2,397 | 4 | 8 | 1.00 | 14.5 | 4.6 |
| 29 | A. M. | 2,392 | 5 | 10 | 0.62 | 20.3 | 3.1 |
| | P. M. | 2,383 | 9 | 18 | 2.25 | 34.2 | 3.7 |
| 30 | A. M. | 2,379 | 4 | 8 | 0.50 | 28.5 | 3.2 |
| | P. M. | 2,376 | 3 | 6 | 0.75 | 27.2 | 3.3 |
| Dec. 1 | A. M. | 2,379 | −3 | −6 | −0.37 | 17.0 | 3.5 |
| | P. M. | 2,372 | 7 | 14 | 1.75 | 30.0 | 6.3 |
| | | 2,419 | (2) | | | | |
| 2 | A. M. | 2,415 | 4 | 8 | 0.50 | 23.8 | 4.6 |
| | P. M. | 2,410 | 5 | 10 | 1.20 | 36.2 | 3.1 |
| 3 | A. M. | 2,401 | 9 | 18 | 1.13 | 30.0 | 3.7 |
| | P. M. | 2,397 | 4 | 8 | 1.00 | 37.4 | 6.9 |
| 4 | A. M. | (1) | | | | | |
| | P. M. | (1) | | | | | |
| 5 | A. M. | (1) | | | | | |
| | P. M. | (1) | | | | | |
| 6 | A. M. | 2,639 | (2) | | | | |
| | P. M. | 2,636 | 3 | 6 | 0.75 | 30.0 | 1.6 |
| 7 | A. M. | 2,637 | −1 | −2 | −0.12 | 25.9 | 3.0 |
| | P. M. | 2,635 | 2 | 4 | 0.50 | 33.7 | 2.9 |
| 8 | A. M. | 2,635 | 0 | 0 | 0.00 | 27.2 | 3.9 |
| | P. M. | 2,628 | 7 | 14 | 1.75 | 40.4 | 2.5 |
| 9 | A. M. | 2,625 | 3 | 6 | 0.37 | 36.8 | 4.4 |
| | P. M. | 2,617 | 8 | 16 | 2.00 | 34.6 | 6.0 |
| 1916. | | | | | | | |
| Feb. 14 | 3:30 P. M. | 2,538 | (2) | | | | |
| 15 | 9:30 A. M. | 2,535 | 3 | 6 | 0.33 | 25.8 | 3.7 |
| | 4:30 P. M. | 2,530.5 | 4.5 | 9 | 1.30 | 35.8 | 3.0 |
| | | 2,749 | (2) | | | | |
| 16 | 9:30 A. M. | 2,746 | 3 | 6 | 0.37 | 24.4 | 3.7 |
| | 4:30 P. M. | 2,738 | 8 | 16 | 2.00 | 38.0 | 3.0 |
| | | 2,770 | (2) | | | | |
| 17 | 11:00 A. M. | 2,766.7 | 3.3 | 6.6 | 0.35 | 24.8 | 4.2 |
| | 4:30 P. M. | 2,763 | 3.7 | 7.4 | 1.35 | 32.9 | 2.4 |
| 18 | 10:00 A. M. | 2,748 | 15.0 | 3.0 | 1.72 | 27.4 | 11.6 |
| | | 2,794 | (2) | | | | |
| | 4:30 P. M. | 2,785 | 9 | 18 | 2.77 | 35.8 | 9.3 |
| | | 2,812 | (2) | | | | |
| 19 | 9:30 A. M. | 2,811 | 1 | 2 | 0.12 | 27.8 | 5.4 |
| | 4:30 P. M. | 2,804 | 7 | 14 | 1.75 | 36.9 | 3.1 |
| | | 3,217.4 | (2) | | | | |
| 20 | 8:30 A. M. | 3,216 | 1.4 | 2.8 | 0.17 | 25.7 | 5.9 |
| | 4:30 P. M. | 3,210.9 | 5.1 | 10.2 | 1.27 | 34.2 | 3.2 |
| | | 3,067.1 | (2) | | | | |
| 21 | 8:30 A. M. | 3,065.2 | 1.9 | 3.8 | 0.22 | 27.6 | 7.6 |
| | 4:30 P. M. | 3,057.7 | 7.5 | 15.0 | 1.87 | 34.4 | 8.0 |
| 22 | A. M. | (1) | | | | | |
| | P. M. | (1) | | | | | |
| 23 | 11:00 A. M. | 3,073.4 | (2) | | | | |
| | 4:30 P. M. | 3,069.2 | 4.2 | 8.4 | 1.53 | 33.7 | 2.5 |
| | | 3,095 | (2) | | | | |
| 24 | 8:30 A. M. | 3,092.6 | 2.4 | 4.8 | 0.30 | 22.0 | 4.0 |
| | 4:30 P. M. | 3,089.2 | 3.4 | 6.8 | 0.85 | 37.7 | 3.0 |
| | | 3,137.9 | (2) | | | | |
| 25 | 9:30 A. M. | 3,133.2 | 4.7 | 9.4 | 0.59 | 22.0 | 4.6 |
| | 4:30 P. M. | 3,128.0 | 5.2 | 10.4 | 1.30 | 37.3 | 2.2 |

(*) Readings were taken in November and December at 8:30 a. m. and 4:30 p. m.; in February, somewhat irregularly as noted.

[1] Snowstorm. [2] Refilled to top.

with temperature or wind velocity as the factor of humidity is also a variable quantity. The graphs in figure 1 show that in this winter evaporation varied closely with temperature, and that where deviations occurred they could frequently be explained by the wind velocity curve, as on the night of November 19, of November 22, and particularly the night of February 17 and the day of the 18th. In other cases it will be noted that the evaporation was in accord with neither temperature nor wind velocity, as on November 20, when the deviation was apparently due to the great change of humidity accompanying a cyclonic disturbance.

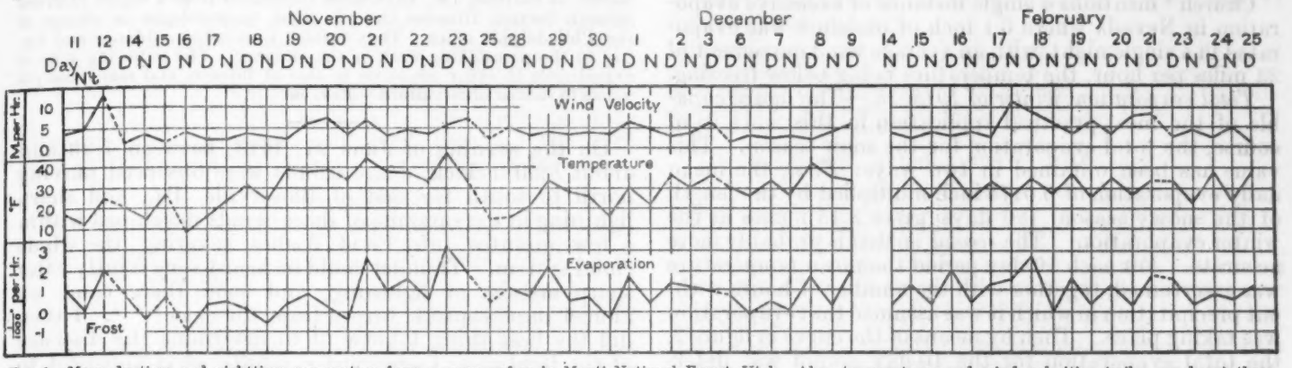


FIG. 1.—Mean daytime and nighttime evaporation from a snow surface in Manti National Forest, Utah. Also, temperatures and wind velocities (miles per hour) there, November 11, 1915, to February 25, 1916.

Solid lines indicate continuous observations; broken lines indicate interrupted observations.

In figure 2 the evaporation is plotted on the basis of temperature, the curve showing a rapid increase of evaporation with rising temperature. In preparing this graph the evaporation values for each day and night appearing in figure 1 were segregated into 5-degree groups, according to the mean temperature of the period of evaporation. Thus the mean hourly evaporation recorded on days and nights whose mean temperatures were between 10° and 15° F. were placed in one group, those recorded in periods whose mean temperatures were 15° to 20° in the second, and so on. The widely varying values in each group were then averaged and the means plotted on the chart, these points being indicated by small circles, which formed the basis for drawing the harmonized curve. The mean hourly diurnal evaporation for the period of observation was also determined, with the mean diurnal temperature for the same period. The mean nocturnal evaporation with the corresponding mean temperature was also ascertained. The first is represented by the X above the curve and the second by the X below. The fact that the diurnal evaporation is higher than it should be considering the mean diurnal temperature and that the nocturnal evaporation is abnormally low, can not be explained by wind velocity as the mean daytime velocity is 4.52 miles per hour and the nocturnal 4.58, but must be due to the higher humidity at night and to the direct effect of insolation during the day.

Rolf [1] has reported a similar investigation conducted in Lapland in which enameled pans were used instead of glass jars, from which formulas were deduced for determining the condensation upon a snow surface under a number of different conditions. For the winter season while the ground is entirely snow covered, his formula is:

$$C = +0.0174(F-f)t,$$

in which $C$ is the condensation (evaporation when its sign becomes minus), $F$ is the actual vapor pressure of the air, $f$ is the maximum vapor pressure at the temperature of the snow layer, and $t$ is the time of exposure in hours. This formula was used in a number of typical cases in the work done at the Utah Experiment Station, to test the applicability of the formula to local conditions. The computed values, however, varied widely and irregularly from the observed quantities, the actual evaporation usually being two or three times greater than computed, particularly at higher evaporations. This was not due to high wind velocities as they were about the same as those recorded by Rolf in Lapland. It therefore appears that so far as the writer's observations go this formula is of little value in attacking the problem of snow evaporation under conditions found in the western mountain ranges. A possible source of inaccuracy lies in the assumption worked out by Rolf that the temperature of the superficial snow layer remains about 3.5 degrees (C.) lower than the surrounding air. When actual snow-surface temperatures shall have been taken the results may be more consistent. It seems certain that the difference in temperature between the snow and air would not be the same under conditions found in Lapland and those in the mountains of Utah, where the humidity is much lower and the insolation much more intense.

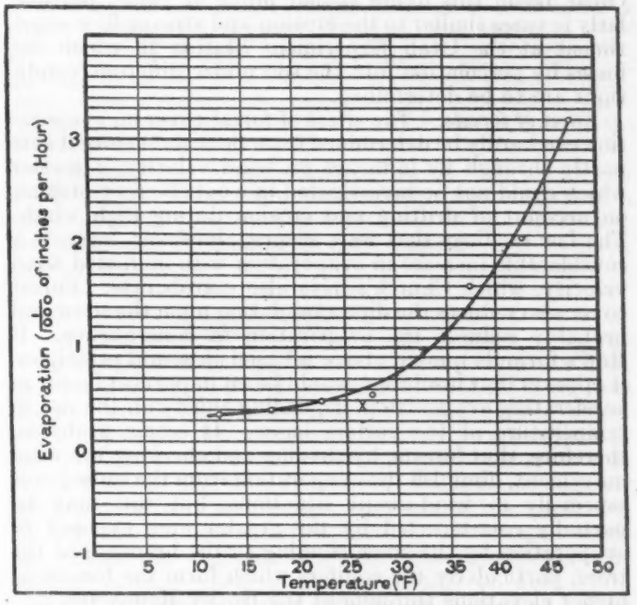


FIG. 2.—Relation of evaporation to temperature at Manti National Forest station, Nov. 11, 1915–Feb. 25, 1916.

[1] *Rolf, B.* Note sur la condensation et l'evaporation qui se produisent à la surface p'une couche de neige. Ark. f. Mat., astron. och fysik, Bd. 9, No. 35, p. 47.

Horton [2] concluded, after noting the evaporation of snow in the outer can of the standard raingage, that for fairly cold weather without heavy winds, with air usually clear, the evaporation amounts to about 1 inch of water per month during the winter at Albany, N. Y. This is about twice the average monthly value obtained in Utah by the writer.

Church [3] mentions a single instance of excessive evaporation in Nevada where 0.1 inch of moisture was evaporated in a single night, with an average wind movement of 33 miles per hour, the temperature being below freezing.

*Total evaporation, winter of 1915–16.*—The figure capable of the most practical application in this work is, of course, the total evaporation for the snow season. This value has been obtained in two ways: *First*, the mean daily evaporation of 0.0175 inch multiplied by the length of the snowy season, 180 days, gives 3.15 inches as the winter evaporation. The *second method* is probably more accurate. For each 10-day period the mean temperature was ascertained, together with the number of hours without precipitation in which it was assumed that evaporation was taking place. Then by means of the curve in figure 2, the total evaporation for the 10-day period was determined. By adding all of these periods together, the total of 2.80 inches was obtained for the winter. It seems evident therefore that under conditions existing at the Utah Experiment Station—and which may hold for all the higher parts of the mountains of Utah—3 inches is a fair figure for the winter evaporation of 1915–16. The water equivalent of the snowfall in the same locality for the winter of 1915–16 was 21.91 inches, so that approximately 14 per cent of the total snowfall was evaporated into the air. In making careful snow surveys in the Great Basin this figure should prove of value, particularly in cases similar to the erosion and stream-flow experiment at the Utah Experiment Station in which the losses by percolation into the soil under different conditions are to be determined.

*Effect of forests.*—The effect of forest cover on evaporation can hardly be determined from these data since it acts partly through its influence on wind velocity, a matter which could not be investigated in a satisfactory manner on account of drifting and erosion during high winds. The few readings that were secured, however, indicate a considerable increase in evaporation with increased wind velocity, which Church's data also corroborate. Forest cover also reduces the direct insolation upon the snow and probably reduces the evaporation in consequence. If Rolf's formula quoted above is based on sound principles, it appears that insolation would be an important factor in accelerating evaporation, depending chiefly on the rise in temperature of the surface snow. It seems probable, therefore, that forests, by shading and checking the wind movement, diminish the evaporation from the snow cover especially in wind-swept situations; but this may be partially counteracted by the greater area exposed to evaporation by the snow clinging to the branches of the trees, particularly the conifers which form the forests at higher elevations throughout the Rocky Mountains.

## DARK DAY IN JAMAICA.

In the MONTHLY WEATHER REVIEW for January, 1917, page 12, Mr. Maxwell Hall, meteorologist to Jamaica, reported an observation of the dark day of May 19, 1780, from Jamaica. The editor there suggested that the observation was perhaps that of the effects of a local or near-by forest fire. Mr. Hall replies that as there are no forest fires in Jamaica, the woods always being too green, the explanation must be sought elsewhere.

[2] *Horton, R. E.* MONTHLY WEATHER REVIEW, 1914, 42: 99.
[3] *Church, J. E., jr.* The progress of the Mount Rose Observatory 1906–1912. Science (N. S.), December 6, 1912, 36: 796.

## DISTANCE AT WHICH THUNDER CAN BE HEARD.

The following observations by Cooperative Observer Clarence E. Miller, at Carlisle, Pa., have been condensed from a report received through Section Director Geo. S. Bliss, meteorologist in charge of the Philadelphia office. They furnish interesting evidence and testify to the painstaking work of the observer. The following note of experiences in other countries is also of interest, and may rouse yet others to similar observations.—EDITOR.

On the evening of June 27, 1913, between 7:30 and about 8:30 o'clock, dense clouds were observed moving north to south far east of Bloserville, Pa., and sharp lightning in the summits of these clouds developed within a few minutes into vivid flashes covering the whole cloud system. Thunder could be heard very faintly after sharp streaks of lightning; and soon there came an almost imperceptible breeze from the east * * *. I then did the best thing I knew of to determine the distance of the lightning: I observed carefully what appeared to be the heaviest streaks of lightning and counted at such a rate that every 5 counts would be equivalent to a mile [traveled by the sound]. Two others with me I had do the same thing to check my counts. We kept this up for 10 minutes or more and were surprised to find that the report of the thunder followed the flash of lightning in from 170 to 175 counts. The time between flash and thunder was almost 3 minutes each time; and the report of the thunder was quite distinct although only the heavy "bump-ump-ump" was heard without a rolling, rumbling sound. This meant the storm was about 30 to 35 miles distant; and inquiries from other observers in Harrisburg developed the fact that this identical storm traveled north to south along a line through Hummelstown and Middletown, where it attained great severity. This storm was therefore actually 30 to 40 miles distant from us while observing it.

On the night of July 1, 1913, at dusk I observed contrasted against the dense, fog-like haze which had opposed the sun's rays for an hour preceding sunset, a lone small cloud of very dark appearance and slowly increasing in size. At dark I observed a flash of lightning in the cloud, followed in a few minutes by another flash, and then by many more in rapid succession, accompanied by heavy thunder. A number of persons were with me, and by counting the interval between lightning and thunder we estimated the storm to be 10 to 12 miles distant. It lasted about half an hour and died out as rapidly as it came up. The sound of the thunder was terrific and I am sure could have been heard at two to three times the distance we were from the storm. Later inquiry showed that this storm was the violent, tornado-like destructive one that visited Carlisle, Pa., and that it was 10 to 12 miles distant. I am certain the thunder carried twice as far.

On the night of August 18, 1913, we observed a storm south-southeast of Bloserville, Pa., in the direction of Gettysburg, with vivid and continuous lightning. Although there was a wind from the northeast [i. e., a cross wind], the thunder could be heard quite plainly at times. The exact location of this storm I have not been able to determine, but we could see plainly that it was not on the northern side [i. e., his side] of South Mountain which was 15 miles away, and the clouds suggested that it was considerably beyond the other side of that ridge. [It was therefore between 16 and 18, perhaps 20, miles distant].

On July 13, 1917 (Friday night), I could hear very distant thunder about 10 p. m. from southeast of Carlisle, Pa., and could see the lightning flashing; but could not see any clouds because of the buildings. About 4 p. m. and later of the same day I had been able to observe dense thunder clouds far to the south-southeast, and later no other clouds appeared where I had seen these; so that the thunder heard at 10 p. m. may have come from the continuation of the same storm. The clouds at 4 p. m. were too far away for me to hear any thunder above the noise of the street traffic, and while the storm must have travelled quite a distance between 4 and 10 p. m., yet if the thunder at 10 p. m. was from the same storm it must have been still very distant. The very light southeast wind at the time was, of course, favorable.

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In this connection the following extracts from a relatively recent note in another publication [1] will be of interest to Mr. Miller:

It is rather rarely the case that the flashes in a distant thunderstorm are so spaced that one can tell certainly to which flash a particular peal of thunder belongs: hence the difficulty of testing the [old time] figures. Such an opportunity was, however, presented to a well-known German meteorologist, Dr. R. Henning, while he was visiting a summer resort on the Baltic [Aug. 4–5, 1911, in Zinnowitz]. From his bed one night he observed the flashes of a thunderstorm far out at sea, at intervals of several minutes. The thunder was faint, but distinctly audible. On "counting seconds" he found that from 80 to 90 seconds and upward elapsed between lightning and thunder. The maximum interval was 96 seconds.

Commenting on this observation the editor of the Meteorologische Zeitschrift [Nov. 1911, **28**:538] states that in northern Germany intervals of from 80 to 85 seconds between lightning and thunder have frequently been recorded. On the coast, with an abnormal distribution of atmospheric density, much greater intervals are sometimes observed. At Norden, East Friesland, C. Veenema has on several occasions noted intervals as great as 140 seconds. At ordinary temperatures of the air this would correspond to a distance of about 29 miles. In one case this observer believed the interval to have been 310 seconds, representing a distance of about 65 miles.

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### *William Bullock Clark, 1860–1917.*

By W. J. HUMPHREYS, Professor of Meteorological Physics.

[Dated: Weather Bureau, Washington, D. C., Aug. 18, 1917.]

[By direction of the Chief of Bureau.]

Dr. William Bullock Clark, professor of geology in the Johns Hopkins University, and director of the State Weather Service of Maryland, died from heart failure on July 27, at North Haven, Me.

Some of Dr. Clark's ancestors were among the earliest colonists. Two of them came to Plymouth, Mass., on the *Mayflower*. He was born at Brattleboro, Vt., December 15, 1860. His education was at the high school of Brattleboro, Amherst College (A.B. 1884, LL.D. 1908), University of Munich (Ph. D. 1887), Berlin, and London.

Dr. Clark's entire professional career, despite numerous offers to go elsewhere, was spent at one institution, the Johns Hopkins University, where he was instructor from 1887 to 1889, associate from 1889 to 1892, associate professor from 1892 to 1894, and professor and head of the department of geology since 1894.

In addition to carrying on numerous investigations of his own, Dr. Clark was even more productive as organizer and director of various public services, such as the Maryland State Weather Service; the Maryland Geological Survey; the Maryland State Board of Forestry; and many others. A brief outline of the purposes and results of the first of these will, perhaps, suffice to indicate the usual thoroughness of his plans and tenacity of his purposes.

This service, the Maryland State Weather Service, was organized May 1, 1891, under the joint auspices of the Johns Hopkins University, the Maryland Agricultural College, and the U. S. Weather Bureau, with Dr. Clark as Director, a position he held continuously until his death, more than 26 years later.

In a letter to the governor of Maryland, dated July 1, 1899, transmitting the first volume of a new series of reports, Dr. Clark says:

The Board of Control plan to publish in the near future a full account of the climatic features of Maryland, in which the physiography, the meteorology, the hydrography, the medical climatology, the agricultural soils, the forestry, the crop conditions, and the flora and fauna of the State will be considered.

The last report, dated January, 1916, says:

The State Weather Service in addition to the publication of many earlier reports has issued three large comprehensive volumes as follows:

Volume One deals (1) with the Physiography of the State, in which the character of the lowlands and the highlands, the drainage channels and the shore lines of the estuaries, bays and ocean front are described as a basis of climatic differentiation, and (2) with the Meteorology of the State, in which the different factors relating to rainfall and temperature throughout the State are discussed in much detail. This latter report is accompanied by a series of maps showing graphically the distribution of rainfall and temperature for each month of the year.

Volume Two deals with the Weather and Climate of Baltimore and is a very exhaustive study of all available records relating to the meteorology and climatology of the chief center of population in the State. It represents the most comprehensive investigation that has ever been given to any municipality in the country.

Volume Three deals with the Plant Life of Maryland in its relation to climatic factors. The distribution of plant life, or ecology, is fully discussed; also crop distribution, since this is dependent likewise on climatic factors. Several well-known experts were employed in this study and the volume is recognized as possessing much practical as well as scientific value.

The Service is now engaged in a detailed study of the climatic features of the several counties. * * *

The Service is also engaged in a quantitative study of the results of climatic factors upon vegetation, this work being conducted under the direction of Prof. B. E. Livingston of the Johns Hopkins University. By growing various cultivated plants at different stations throughout the State under similar soil conditions and keeping a careful quantitative record of their growth, changes and physiological activity it is expected that accurate data will be obtained showing the results of the varying climatic conditions in crop production.

This indeed is a remarkable showing. In the death of Dr. Clark, meteorology and climatology have lost a most efficient promotor, geology one of its ablest exponents, and the public a most capable and devoted servant.

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#### WILLIAM BULLOCK CLARK.

In another place the bureau comments officially on the passing of Prof. W. B. Clark, founder and first director of the Maryland State Weather Service.

Five years of association with Dr. Clark inspired in the present writer a sincere regard for him as a man and a friend. To his associates and the students in his department Dr. Clark was not merely a teacher but a brother and a friend, always ready to recognize and encourage the slightest show of enterprise, effort, or ability; always cheering and heartening all about him and unconsciously offering his own great store of energy and enthusiasm as a stimulus to even the humblest of his associates. In the field Clark was the best companion one could desire, full of work and full of humor, a splendid planner of excursions and expeditions, a no less successful executive in carrying them to a pleasant and profitable close.

While primarily devoted to Geology and Palæontology, and making a brilliant mark for himself in the latter branch, he developed abundant enthusiasm for helpful work in other branches of science. The series of splen-

[1] Scientific American, New York, Jan. 20, 1912, **106**:77.

didly planned and sumptuously appareled reports on the geology of Maryland were fully matched by the corresponding series of reports on the climate and weather of the State. Moreover the two sciences were by no means held rigidly apart in his philosophical view of things. The contents of the elegant epoch-making first Report of the Maryland Weather Service in 1899 testified to Clark's broad understanding of the interrelation necessarily existing between geology and meteorology. The volume was full of promise for the climatologist in Maryland, and the promise was richly fulfilled. Taking advantage of his position as State Geologist, he inserted in each of the county geological reports a more or less detailed chapter on the climate of the county, prepared by an experienced climatologist. Thus there appeared with brief intermissions—

Climate of Allegany County, by O. L. Fassig. 15p. 1900.
Climate of Cecil County, by O. L. Fassig. 13p. 1902.
Climate of Garrett County, by O. L. Fassig. 21p. 1902.
Climate of Calvert County, by C. F. von Herrmann. 37p. 1907.
Climate of Saint Mary's County, by C. F. von Herrmann. 30p. 1907.
Climate of Prince George's County, by W. H. Alexander. 21p. 1911.
Climate of Ann Arundel County, by O. L. Fassig. 18p. 1917.

Again in the report of the Maryland Geological Survey, volume 6 (Baltimore, 1906), we find Clark devoting 14 pages (224–237) to a review of the general climate of the State in its bearings on the engineering, roadbuilding, and geological problems peculiar to Maryland.

The second and third volumes of the Maryland Weather Service, as the above quotations show, have also proven patterns and standards for subsequent similar publications for other regions. At least one other treatise, published in the United States in 1913, shows the strong influence exerted by the publications planned by Dr. Clark. E. L. Voss[1] states that he took the plan of Vol. II as a model for his own monograph on the rainfall of South America, being unable to find another work as good.

It is but just to point out here that in all this work for Maryland geology and climatology Prof. Clark secured and retained the hearty cooperation of the much wealthier respective Federal services,[2] as well as of the Maryland State Agricultural College (through Milton Whitney), so that his energy and address enabled the State to which he devoted his life's service to profit greatly by resources beyond its own confines. And not the State alone has profited. The strong State institutions he understood to build up were buttresses in time of need to Johns Hopkins University, and the most convincing proofs of how an advanced university increases the wealth of the State that harbors her, by training the sons of the State for higher labors in the service of that State.—C. A., jr.

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### *Thomas Mikesell, 1845–1917.*

By J. WARREN SMITH, Meteorologist in Charge.
[Division of Agricultural Meteorology, Weather Bureau, Aug. 25, 1917.]

In the death of Thomas Mikesell at Wauseon, Ohio, July 18, 1917, the world lost an earnest student of nature and a remarkable phenological record was brought to a close.

Mr. Mikesell was born on the homestead farm 1 mile north of Wauseon, August 9, 1845, and was the son of William and Margaret (Bayes) Mikesell, who moved from western Pennsylvania in 1837. In June, 1863, he enlisted in Company H, Eighty-sixth Volunteer Infantry, and served until February 10, 1864.

Mr. Mikesell's special interest in meteorology dated from 1865, when he took up the study of Brocklesby's Meteorology. He soon began keeping a journal of the weather, and when, in the fall of 1869, he returned to the farm where he was born, he obtained some meteorological instruments and began a series of careful records that were not terminated until June 27, 1917, less than one month before his death. Beginning with 1882 self-registering thermometers were in use, but during all of the period he took eye readings three times daily, and

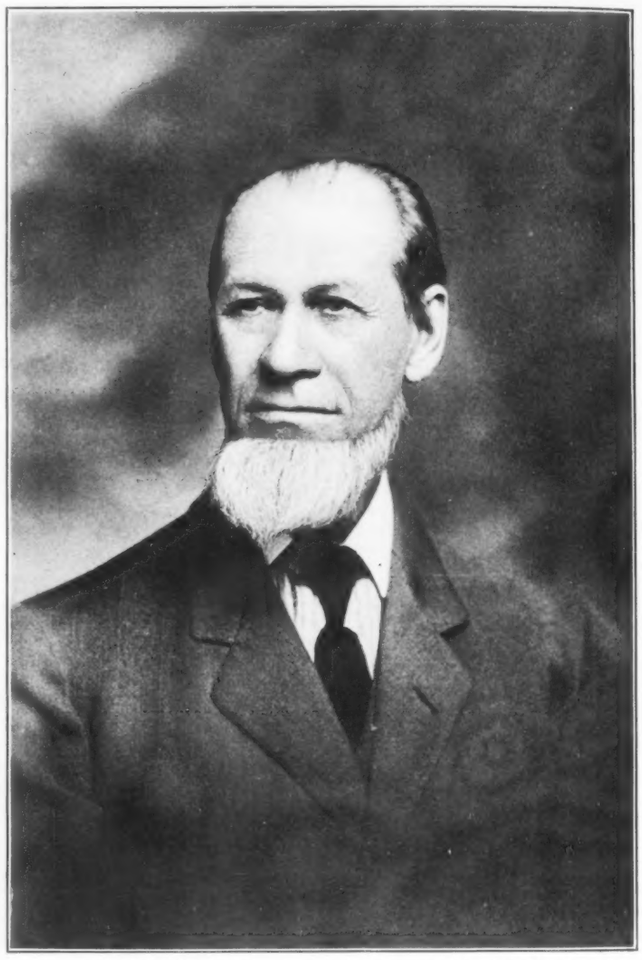

FIG. 1.—Thomas Mikesell, 1845-1917. Cooperative observer of the U. S. Signal Service, of the Ohio State Meteorological Service, and of the U. S. Weather Bureau from 1870 to 1917, at Wauseon, Ohio.

previous to 1882 frequent observations were made at the early morning and during the warmest part of the day to obtain the extremes of temperature for each twenty-four hours.

It was in the phenological observations, however, that the prodigious work of Mr. Mikesell, as well as his ability for observing and recording in detail passing events, was brought out. In Monthly Weather Review Supplement No. 2 (Washington, 1915) this bureau published tables showing a good many of the meteorological and phenological records kept by Mr. Mikesell. One table shows 8 different important dates in the development of 16 differ-

[1] *Voss, Ernst Ludwig.* Die Niederschlagsverhältnisse von Südamerika. Peterm. Mitteil., Ergänz'bd. 33, hft. 157. Gotha, 1907. *See* p. iv of the Vorrede.
[2] See MONTHLY WEATHER REVIEW, June 1895, **23**:210; and Oct., 1899, **27**:472–3.

ent kinds of fruits, together with the quality and quantity, from 1883 to 1912. Another gives 7 similar items for 20 different fruits and garden crops, another 8 items for 48 different fruit trees, shrubs, and vines, while a fourth table shows the dates of blossoming of 114 different plants during the period of discussion. Still other tables showed the daily maximum, minimum, and mean temperatures, and daily rainfall, the dates of first and last frosts, freezing weather; temperatures of 0°, 20°, and 90° F.; first and last snows, thunderstorms, etc.

Even these tables, however, include only part of the large number of records kept by this remarkable man. For example, the published table gives the following dates for the "King" apple: Buds started, first fully formed leaf, in full leaf, first bloom, full bloom, fruit ripe, complete change in foliage, divested of leaves, quantity of fruit, and quality of fruit; his manuscript records, however, show the same data for all the different varieties of apples raised in that vicinity. In the published tables data are given for the "Bartlett" pear, the "early Richmond" cherry, "Concord" grapes, etc., while his record covers all the different varieties of these various fruits that are grown in that latitude. The published table gives likewise the dates: Planted, above ground, in blossom, ripe, ready for use, per cent of good crop, and quality of crop, for 20 different field and garden crops; but his record includes the same data for a large number of different varieties of all these crops.

His records were not confined to the life history of plants, but as might be expected from one who was so interested in the world of nature about him, he shows the movement of 60 different varieties of birds. The dates when each was first seen together with the number observed, date next seen, date when they became common, and the dates when last seen, were very carefully observed. He became an associate member of the American Ornithologist Union in 1885 and was a correspondent of this organization as well as of the Division of Economic Ornithology of the U. S. Department of Agriculture. His manuscripts also include some records for a great part of the insect and small animal life that may be found in rural districts in the latitude of his home in northwestern Ohio. Nothing escaped his eye apparently and the coming and going of a great variety of butterflies, moths, frogs, etc., *ad infinitum*, almost.

Quiet, unobtrusive, yet interested and taking an active part in the social, religious, and political life of his community, the wonderful thing is that any one man could find time for observing and keeping systematic record of so many different phases of the physical life which surrounded him.

## SECTION III.—FORECASTS.

### FORECASTS AND WARNINGS FOR JULY, 1917.

By H. C. FRANKENFIELD, Supervising Forecaster.

[Dated Washington, Aug. 11, 1917.]

#### GENERAL PRESSURE DISTRIBUTION OVER THE NORTHERN HEMISPHERE EXCEPT EUROPE AND INTERIOR ASIA.

Pressure was generally high over the Pacific Ocean, although only slightly so over the southern portion during the first half of July, 1917. Over the Aleutian Islands there were several well-defined periods of alternate low and high pressure, the former prevailing at the beginning and end of the month. Over Alaska moderately low pressure predominated, although during the second decade the average was slightly below the normal. The same general distribution prevailed over northwestern Canada and the northwestern portion of the United States in less pronounced form, but over the remainder of Canada and the United States, except the Canadian Maritime Provinces and the coast States, there was an excess of high pressure during the second half of the month, except during the last few days. Over the Atlantic Ocean high pressure ruled with only a few days of normal conditions.

#### WASHINGTON DISTRICT.

There were no storms during the month that justified the display of storm warnings, and none was ordered.

Small-craft warnings were displayed locally on July 1 and 29 on the Great Lakes for moderately strong winds, mainly thundersqualls, and on July 11 from Sandy Hook, N. J., to Boston, Mass.

On July 6 there were some indications of a disturbance south of the Island of Barbados, and the usual cautionary advices were issued. Later developments showed that a very moderate disturbance moved northwestward and disappeared some distance south of the Island of Santo Domingo, the observer at the city of Santo Domingo reporting some damage off the coast.

#### WARNING FROM OTHER DISTRICTS.

*Chicago forecast district.*—No warnings were issued during July, 1917, except a local small-craft warning at Chicago on the morning of the 1st, and warnings of possible frosts in the cranberry districts of Wisconsin on the 2d and 3d.—*Charles L. Mitchell, Assistant Forecaster.*

*New Orleans forecast district.*—The summer type of weather prevailed, without unusual features during July, 1917. The winds on the coast were generally light to moderate, except on July 21, when a velocity of 46 miles was recorded at Corpus Christi, Tex., during a local storm of which no indication appeared on the weather maps.

No warnings were issued during the month.—*R. A. Dyke, Assistant Forecaster.*

*Denver forecast district.*—No special warnings were issued during July, 1917. The month was remarkably dry over practically the entire district, although there were only three 12-hour periods during the month for which thunderstorms were not reported from some part of the district. With few exceptions these storms were unattended by appreciable rainfall.

There was a remarkable absence of high winds and no fire-weather warnings were issued.—*Frederick H. Brandenburg, District Forecaster.*

*San Francisco forecast district.*—During July, 1917, pressure was persistently high over Dutch Harbor and also along the Oregon, Washington, and British Columbia coasts. Barometric maxima along the north Pacific coast moved intermittently and slowly north or south, and every few days sent out an offshoot that crossed the Rocky Mountains and then disintegrated or drifted slowly eastward usually changing in form and decreasing.

As an offshoot separated from the parent HIGH, a barometric trough would extend from British Columbia or Alberta south through California to southern Arizona, and the weather, especially in the northern portion of the district, would become unsettled with light showers in the valleys and heavy showers in the mountains. As a whole the month was very dry and warm. In Nevada the highest temperatures of record occurred at Reno on the 11th and at Tonopah on the 12th.

Fire-weather warnings were issued on July 10, 13, 25, and 31. Those on the 10th and 13th were well verified; the one on the 31st was verified over the greater portion of the district, but not in all places. The warning issued on the 25th was a failure, and on the following day all recipients were notified of the sudden change in pressure, which, besides nullifying the warning, caused much less hazardous fire-weather conditions.

No storm warning was ordered, and none was needed.

The hot and dry weather that prevailed during a considerable portion of the month, while a source of damage and injury in many respects, nevertheless afforded several excellent opportunities for illustrating the utility and value of the fire-weather warnings that were issued. As previously stated, all but one of these warnings were well verified, and, while there were many fires, none was of consequence, and written expressions of commendation from forest supervisors, fire wardens, and others, regarding the warnings, were numerous.—*E. A. Beals, District Forecaster.*

# SECTION IV.—RIVERS AND FLOODS.

## RIVERS AND FLOODS DURING JULY, 1917.

By ALFRED J. HENRY, Professor of Meteorology.

[Dated Washington, Aug. 27, 1917.]

The rainfall of July, 1917, was irregularly distributed as is usual at this season of the year. The total fall for the month was in excess of 10 inches over a considerable portion of North Carolina and also over a narrow strip along the coast of South Carolina and in northeastern Tennessee and southeastern Mississippi.

The rivers of the Carolinas were in moderate flood during the last decade of the month as shown in Table 1, and, while conditions at times were threatening, serious loss or damage did not occur.

The lower Mississippi, while in flood during the closing days of June, fell steadily during the month as may be seen from the hydrographs on Chart I (XLV—68).

*Spring flood in the lower Colorado.*—Owing to temperature conditions in the upper watershed, the tributaries of the Colorado were rather high on the first of the month but declined steadily thereafter. The lower Colorado crested at Topock, Ariz., on the 3d at a stage of 23.2 feet, or 9.2 feet above flood stage.

There was some loss to levees in the Palo Verde Valley, Riverside County, Cal., as a result of this flood.

The spring flood in the Columbia passed off without untoward incidents.

A severe local rainstorm in the vicinity of Lansing, Iowa, and Victory, Wis., on the 21st and again on the following day caused a flood in Bad Axe River, with a heavy loss to railroads and crops.

*Losses by floods in July, 1917.*

| District. | Tangible property: Bridges, highways, etc. | Crops. | | Live stock; other property. | Suspension of business. |
|---|---|---|---|---|---|
| | | Matured. | Prospective. | | |
| North Carolina | | | $5,000 | | |
| Mississippi | | | 125,000 | | |
| California | $5,000 | | 40,000 | | $20,000 |
| Iowa and Wisconsin | 100,000 | | 50,000 | | |
| Maine * | 150,000 | | 25,000 | | 25,000 |
| Totals | 255,000 | | 245,000 | | 45,000 |

* Mostly from breaking of dam on Cobbosseecontee River in June.

Hydrographs for typical points on several principal rivers are shown on Chart I. The stations selected for charting are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.

TABLE 1.—*Floods in Atlantic coast and Great Lakes drainage during July, 1917.*

| River. | Station. | Flood stage. | Above flood stages—dates. | | Crest. | |
|---|---|---|---|---|---|---|
| | | | From— | To— | Stage. | Date. |
| *Atlantic.* | | *Feet.* | | | *Feet.* | |
| Roanoke | Weldon, N. C. | 30 | | | 27.4 | 28 |
| Tar | Tarboro, N. C. | 18 | 29 | (1) | 19.6 | 30 |
| Do. | Greenville, N. C. | 13 | 27 | (1) | 14.6 | 31 |
| Fishing Creek | Enfield, N. C. | 14 | 26 | 28 | 14.3 | 27, 28 |
| Neuse | Neuse, N. C. | 14 | 24 | 24 | 14.1 | 24 |
| Do. | Smithfield, N. C. | 13 | 24 | 27 | 14.7 | 25, 26 |
| Cape Fear | Elizabethton, N. C. | 22 | 22 | 25 | 25.1 | 23 |
| Santee | Rimini, S. C. | 12 | 21 | 29 | 13.0 | 24-27 |
| Do. | Ferguson, S. C. | 12 | 23 | 26 | 12.3 | 24, 25 |
| | | | 28 | 29 | 12.9 | 28 |
| Wateree | Camden, S. C. | 24 | | | 23.4 | 22 |
| *Great Lakes.* | | | | | | |
| Maumee | Fort Wayne, Ind. | 15 | | | 14.2 | 7 |

[1] Continued into August.

TABLE 2.—*Floods in Mississippi River and tributaries, July, 1917.*

| River. | Station. | Flood stage. | Above flood stages—dates. | | Crest. | |
|---|---|---|---|---|---|---|
| | | | From— | To— | Stage. | Date. |
| *Mississippi proper.* | | *Feet.* | | | *Feet.* | |
| Mississippi | Arkansas City, Ark. | 42 | (1) | 3 | 46.6 | [2] 27 |
| Do. | Greenville, Miss. | 42 | | | 37.9 | 1 |
| Do. | Vicksburg, Miss. | 45 | | | 43.7 | 1 |
| Do. | Natchez, Miss. | 46 | | | 42.5 | 2-5 |
| *Eastern tributaries.* | | | | | | |
| Scioto | Circleville, Ohio | 7 | 15 | 16 | 11.5 | 15 |
| Do. | Chillicothe, Ohio | 14 | | | 13.2 | 16 |
| Tennessee | Knoxville, Tenn. | 12 | | | 11.0 | 16 |
| Illinois | Peru, Ill. | 14 | | | 12.8 | 1 |
| Do. | Peoria, Ill. | 16 | | | 14.7 | 1, 2 |
| Do. | Beardstown, Ill. | 12 | (1) | 12 | 19.1 | [2] 17 |
| Do. | Pearl, Ill. | 12 | (1) | 5 | 18.2 | [2] 15, 17 |
| *Western tributaries.* | | | | | | |
| Missouri | Running Water, S. Dak. | 16 | | | 14.6 | 1-3 |
| Do. | Blair, Nebr. | 15 | | | 14.6 | 1 |
| Do. | St. Joseph, Mo. | 12 | | | 11.3 | 2, 7, 8, 9 |
| Do. | Kansas City, Mo. | 22 | (1) | | 20.3 | 1 |
| Grand | Brunswick, Mo. | 10 | (1) | 10 | 11.3 | [2] 30 |

[1] Continued from June. [2] June.

TABLE 3.—*Floods in Pacific coast drainage during July, 1917.*

| River. | Station. | Flood stage. | Above flood stages—dates. | | Crest. | |
|---|---|---|---|---|---|---|
| | | | From— | To— | Stage. | Date. |
| *Colorado Basin.* | | *Feet.* | | | *Feet.* | |
| Colorado | Topock, Ariz. | 14 | (1) | 11 | 23.2 | 3 |
| Do. | Parker, Ariz. | 10 | (1) | ..... | 9.8 | 1, 4 |
| Green | Green River, Wyo. | 9 | (1) | 15 | 11.4 | [2] 28, 29 |
| Do. | Elgin, Utah | 13 | (1) | 9 | 17.5 | [2] 27 |
| *Columbia Basin.* | | | | | | |
| Columbia | Marcus, Wash. | 24 | (1) | 23 | 30.0 | [2] 23–25 |
| Do. | Wenatchee, Wash. | 40 | (1) | ..... | 39.2 | 1 |
| Do. | The Dalles, Oreg. | 40 | (1) | ..... | 36.7 | 1 |
| Do. | Vancouver, Wash. | 15 | (1) | 23 | 24.5 | [2] 22 |
| Pend Oreille | Newport, Wash. | 16 | (1) | 13 | 21.6 | [2] 25–27 |
| Willamette | Portland, Oreg. | 15 | (1) | 22 | 23.8 | [2] 22 |

[1] Continued from June. [2] June.

## MEAN LAKE LEVELS DURING JULY, 1917.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., Aug. 4, 1917.]

The following data are reported in the "Notice to Mariners" of the above date.

| Data. | Lakes.* | | | |
|---|---|---|---|---|
| | Superior. | Michigan and Huron. | Erie. | Ontario. |
| Mean level during July, 1917: | *Feet.* | *Feet.* | *Feet.* | *Feet.* |
| Above mean sealevel at New York | 602.65 | 581.95 | 573.86 | 247.46 |
| Above or below— | | | | |
| Mean stage of June, 1917 | +0.05 | +0.42 | +0.42 | +0.48 |
| Mean stage of July, 1916 | −0.95 | +0.77 | +0.64 | −0.47 |
| Average stage for July, last 10 years | +0.17 | +1.11 | +1.06 | +0.55 |
| Highest recorded July stage | −1.17 | −1.63 | −0.55 | −1.26 |
| Lowest recorded July stage | +1.17 | +2.05 | +2.40 | +2.87 |
| Average relation of the July level to— | | | | |
| June level | +0.2 | +0.1 | −0.1 | −0.1 |
| August level | −0.2 | ±0.0 | +0.2 | +0.3 |

* Lake St. Clair's level: In July, 576.72 feet.

# SECTION V.—SEISMOLOGY.

## SEISMOLOGICAL ABBREVIATIONS USED IN THE INSTRUMENTAL REPORTS.

### CHARACTER OF THE EARTHQUAKE.

I = noticeable.
II = conspicuous.
III = strong.
d = (terræ motus domesticus) = local earthquake (sensible or felt).
v = (terræ motus vicinus) = near-by earthquake (within 1,000 km.).
r = (terræ motus remotus) = distant earthquake (1,000 to 5,000 km. distant).
u = (terræ motus ultimus) = very distant earthquake (beyond 5,000 km.).
$\Delta$ = distance to epicenter.

### PHASES.

P = (undæ primæ) = first preliminary tremors.
PR$n$ = P waves reflected $n$ times at the earth's surface.
S = (undæ secundæ) = second preliminary tremors.
SR$n$ = S waves reflected $n$ times at the earth's surface.
PS = transformed waves; longitudinal (P) to transversal (S) or vice versa.
L = (undæ longæ) = long waves in the principal portion.
M = (undæ maximæ) = greatest motion in the principal portion.
C = (coda) = trailers.
$O$ = time at epicenter.
$L_{rep_1}$ = Long waves reaching the station from the antiepicenter (40,000 km. $-\Delta$).
$L_{rep_2}$ = long waves again reaching the station from the antiepicenter (40,000 km. $+\Delta$).
F = (finis) = end of perceptible trace.

### NATURE OF THE MOTION.

i = (impetus) = abrupt beginning.
e = (emersio) = gradual appearance.
T = period = twice the time of oscillation.
A = amplitude of the earth's movement, reckoned from the zero line.
E, N, or $Z$ attached to a symbol signifies the E–W, the N–S, or the vertical component, respectively, thus:
$A_E$ is the E–W component of A.
$A_N$ is the N–S component of A.
$A_Z$ is the vertical component of A.
} Measured in microns ($\mu$), $\frac{1}{1000}$ mm.

### INSTRUMENTAL CONSTANTS.

T = period of instrument.
V = magnification of instrument.
$\epsilon$ = damping ratio.

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## SEISMOLOGICAL REPORTS FOR JULY, 1917.

W. J. HUMPHREYS, Professor in Charge.

[Dated: Weather Bureau, Washington, D. C., Sept. 4, 1917.]

TABLE 1.—*Noninstrumental earthquake reports, July, 1917.*

| Day. | Approximate time, Greenwich Civil. | Station. | Approximate latitude. | Approximate longitude. | Intensity Rossi-Forel. | Number of shocks. | Duration. | Sounds. | Remarks. | Observer. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CALIFORNIA. | | | | | | | | |
| | *H. m.* | | ° ′ | ° ′ | | | *M. s.* | | | |
| 7 | (Morning) | Owenyo | 36 40 | 113 01 | 6-7 | 1 | ..... | ..... | Broke aqueduct | Wm. Mulholland. |
| 7 | 20 57 | San Luis Obispo | 35 18 | 120 39 | 3 | 2 | 7 | ..... | Rattled windows | U. S. Weather Bureau. |
| 8 | 3 20 | Santa Maria | 34 58 | 120 27 | 2-3 | 1 | 10 | ..... | ..... | Henry Neil, jr. |
| 9 | 5 15 | Bishop | 37 24 | 118 26 | 3 | 1 | ..... | Rumbling | ..... | William Barth. |
| 9 | 22 22 | San Luis Obispo | 35 18 | 120 39 | 4 | 1 | 2 | Loud | ..... | U. S. Weather Bureau. |
| 15 | 19 05 | Mt. Wilson | 34 13 | 118 16 | 4 | 2 | 2 | Rumbling | House creaked | Wendell P. Hoge. |
| 16 | 6 50 | Calexico | 32 41 | 115 30 | 2 | 1 | ½ | Rumbling | Sounds before shock | H. M. Rouse. |
| 21 | 16 50 | Ferndale | 40 35 | 124 16 | 3 | 3 | ..... | None | ..... | M. Eriksen. |
| 26 | 8 31 | San Luis Obispo | 35 18 | 120 39 | 2 | 1 | 2 | None | ..... | U. S. Weather Bureau. |
| | | Santa Maria | 34 58 | 120 27 | 4-5 | 3 | 15 | ..... | Moved furniture | R. E. Collom. |
| | | PORTO RICO. | | | | | | | | |
| 13 | 6 20 | Mayaguez | 18 13 | 67 08 | 5 | 3 | 28 | Faint | ..... | C. Alemar, jr. |
| 27 | 2 01 | Mayaguez | 18 13 | 67 08 | 6 | ..... | 20 | Faint | ..... | C. Alemar, jr. |
| | | San Juan | 18 29 | 66 07 | 6 | 2 | 6 | ..... | Clock stopped | U. S. Weather Bureau. |

TABLE 2.—*Instrumental reports, July, 1917.*

[Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.]

[For significance of symbols see above, p. 373.]

### Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. J. W. Green.

Lat., 57° 03′ 00″ N.; long., 135° 30′ 06″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants: V / $T_0$: E 10 16.6; N 10 15.4

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| 1917. | | | *H. m. s.* | *Sec.* | μ | μ | *km.* | |
| July 25 | ..... | $eL_N$ | 3 25 07 | 19 | ..... | ..... | ..... | |
| | | $eL_E$ | 3 26 24 | 19 | ..... | ..... | ..... | |
| | | $M_E$ | 3 27 44 | 18 | 10 | ..... | ..... | |
| | | $M_N$ | 3 28 17 | 15 | ..... | 20 | ..... | |
| | | $C_E$ | 3 30 — | ..... | ..... | ..... | ..... | |
| | | $C_N$ | 3 35 — | ..... | ..... | ..... | ..... | |
| | | F | 4 15 — | ..... | ..... | ..... | ..... | |
| 27 | ..... | $eP_N$ | 1 11 54 | ..... | ..... | ..... | ..... | |
| | | $eS_N$ | 1 20 02 | 8 | ..... | ..... | ..... | |
| | | $eL_N$ | 1 32 40 | 26 | ..... | ..... | ..... | |
| | | $eL_E$ | 1 34 — | ..... | ..... | ..... | ..... | |
| | | $M_N$ | 1 37 35 | 13 | ..... | 100 | ..... | |
| | | $M_E$ | 1 44 22 | 14 | 60 | ..... | ..... | |
| | | C | 1 45 — | ..... | ..... | ..... | ..... | |
| | | F | 2 44 — | ..... | ..... | ..... | ..... | |
| 27 | ..... | $eP_N$ | 3 19 04 | ..... | ..... | ..... | ..... | Barely discernible on E-W. No phases. |
| | | $eL_N$ | 3 46 46 | 25 | ..... | ..... | ..... | |
| | | $M_N$ | 3 49 50 | 18 | ..... | 20 | ..... | |
| | | C | 3 55 — | ..... | ..... | ..... | ..... | |
| | | F | 4 28 — | ..... | ..... | ..... | ..... | |
| 29 | ..... | $eP_E$ | 22 05 24 | 7 | ..... | ..... | ..... | |
| | | $eS_E$ | 22 15 59 | 8 | ..... | ..... | ..... | |
| | | $eS_N$ | 22 15 08 | 9 | ..... | ..... | ..... | |
| | | $eL_N$ | 22 28 10 | 20 | ..... | ..... | ..... | |
| | | $eL_E$ | 22 33 00 | ..... | ..... | ..... | ..... | |
| | | $M_E$ | 22 17 26 | 9 | 80 | ..... | ..... | |
| | | $M_E$ | 22 38 45 | 20 | 20 | ..... | ..... | |
| | | $M_N$ | 22 38 00 | 18 | ..... | 20 | ..... | |
| | | C | 22 49 — | ..... | ..... | ..... | ..... | |
| 30 | ..... | F | 0 44 — | ..... | ..... | ..... | ..... | |
| 31 | ..... | $e_N$ | 0 21 24 | ..... | ..... | ..... | ..... | Mere tremor of E-W. No phases. |
| | | $e_E$ | 0 38 34 | ..... | ..... | ..... | ..... | |
| | | $L_N$ | 0 39 08 | 20 | ..... | ..... | ..... | |
| | | $M_N$ | 0 43 38 | 16 | ..... | 30 | ..... | |
| | | C | 0 47 — | ..... | ..... | ..... | ..... | |
| | | $F_E$ | 0 57 — | ..... | ..... | ..... | ..... | |
| | | $F_N$ | 1 41 — | ..... | ..... | ..... | ..... | |

### Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat., 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instruments constants: V / $T_0$: E 10 13.9; N 10 18.9

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| 1917. | | | *H. m. s.* | *Sec.* | μ | μ | *km.* | |
| July 27 | ..... | $e_E$ | 1 08 26 | ..... | ..... | ..... | ..... | No well defined phases. |
| | | $e_N$ | 1 09 28 | ..... | ..... | ..... | ..... | |
| | | $M_N$ | 1 27 20 | 16 | ..... | 100 | ..... | |
| | | $M_E$ | 1 34 24 | 16 | 60 | ..... | ..... | |
| | | F | 4 03 — | ..... | ..... | ..... | ..... | |
| 29 | ..... | $e_E$ | 22 11 15 | ..... | ..... | ..... | ..... | Record very faint. |
| | | $M_E$ | 22 57 54 | 17 | 10 | ..... | ..... | |
| | | $M_N$ | 23 05 28 | 20 | ..... | 10 | ..... | |
| 30 | ..... | F | 0 22 — | ..... | ..... | ..... | ..... | |

### California. *Berkeley. University of California.*

Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters.

(See Bulletin of the Seismographic Stations, University of California.)

### California. *Mount Hamilton. Lick Observatory.*

Lat., 37° 20′ 24″ N.; long., 121° 33′ 34″ W. Elevation, 1,281.7 meters.

(See Bulletin of the Seismographic Stations, University of California.)

### California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

(Report for July, 1917, not received.)

### California. *Santa Clara. University of Santa Clara.* J. S. Ricard, S.J.

Lat., 37° 26′ 36″ N.; long., 121° 57′ 03″ W. Elevation, 27.43 meters.

(See record of the Seismographic Station, University of Santa Clara.)

### District of Columbia. *Washington. U. S. Weather Bureau.*

Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters.

Instrument: Marvin vertical pendulum, undamped. Mechanical registration.

Instrumental constants: V / $T_0$: 110 6.4

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| 1917. | | | *H. m. s.* | *Sec.* | μ | μ | *km.* | |
| July 1 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Small quake, beginning about $13^h$ $36^m$; L about $13^h$ $41^m$; and F about $13^h$ $50^m$. No time marks. |
| 4 | ..... | P | 0 57 14 | ..... | ..... | ..... | 8,675 | |
| | | S | 1 07 08 | ..... | ..... | ..... | ..... | |
| | | L | 1 25 30 | 60 | ..... | ..... | ..... | |
| | | L | 1 31 00 | 40 | ..... | ..... | ..... | |
| | | L | 1 37 00 | 24 | ..... | ..... | ..... | |
| | | F | 2 35 00 | ..... | ..... | ..... | ..... | |
| 12 | ..... | L | 12 41 33 | ..... | ..... | ..... | ..... | |
| | | L | 12 43 30 | 20 | ..... | ..... | ..... | |
| | | L | 12 47 00 | 16 | ..... | ..... | ..... | F lost changing sheets. |
| 13 | ..... | iP | 5 19 07 | ..... | ..... | ..... | 2,090 | |
| | | S | 5 22 38 | ..... | ..... | ..... | ..... | |
| | | L | 5 25 00 | ..... | ..... | ..... | ..... | |
| | | F | 5 40 00 | ..... | ..... | ..... | ..... | |
| 25 | ..... | P | 3 28 58 | ..... | ..... | ..... | 6,125 | |
| | | S | 3 36 41 | ..... | ..... | ..... | ..... | |
| | | L | 3 45 15 | ..... | ..... | ..... | ..... | |
| | | L | 3 49 30 | 20 | ..... | ..... | ..... | |
| | | F | 4 30 00 | ..... | ..... | ..... | ..... | |
| 25 | ..... | P | 22 42 44 | ..... | ..... | ..... | 6,140 | |
| | | S | 22 50 28 | ..... | ..... | ..... | ..... | |
| | | L | 23 03 00 | ..... | ..... | ..... | ..... | |
| | | F | 23 30 00 | ..... | ..... | ..... | ..... | |
| 27 | $II_r$ | iP | 1 06 11 | ..... | ..... | ..... | 2,340 | |
| | | S | 1 10 03 | ..... | ..... | ..... | ..... | |
| | | L | 1 13 55 | 16 | ..... | ..... | ..... | C merges with succeeding quake. |
| 27 | $I_u$ | P | 3 02 47 | ..... | ..... | ..... | 7,725 | |
| | | S | 3 11 53 | ..... | ..... | ..... | ..... | |
| | | L? | 3 20 15 | ..... | ..... | ..... | ..... | |
| | | L | 3 24 45 | 20 | ..... | ..... | ..... | |
| | | F | 3 40 00 | ..... | ..... | ..... | ..... | |
| 27 | ..... | P | 16 20 09 | ..... | ..... | ..... | 2,150 | |
| | | S | 16 23 45 | ..... | ..... | ..... | ..... | |
| | | L? | 16 25 50 | ..... | ..... | ..... | ..... | |
| | | L | 16 29 15 | 12 | ..... | ..... | ..... | |
| | | F | 17 30 00 | ..... | ..... | ..... | ..... | |
| 28 | ..... | e | 1 31 05 | ..... | ..... | ..... | ..... | |
| | | S? | 1 39 20 | ..... | ..... | ..... | ..... | |
| | | L | 1 49 00 | ..... | ..... | ..... | ..... | |
| | | F | 2 00 00 | ..... | ..... | ..... | ..... | |
| 29 | ..... | P | 14 55 54 | ..... | ..... | ..... | 4,370? | |
| | | S? | 15 02 02 | ..... | ..... | ..... | ..... | |
| | | L | 15 10 00 | 20 | ..... | ..... | ..... | |
| | | L | 15 22 00 | 20 | ..... | ..... | ..... | |
| | | F | 16 15 00 | ..... | ..... | ..... | ..... | |
| 29 | ..... | P? | 22 11 40 | ..... | ..... | ..... | ..... | |
| | | e | 22 15 06 | ..... | ..... | ..... | ..... | |
| | | L | 22 25 00 | ..... | ..... | ..... | ..... | |
| | | L | 22 52 00 | 40 | ..... | ..... | ..... | |
| | | L | 23 02 00 | 18 | ..... | ..... | ..... | |
| 30 | ..... | F | 1 00 00 | ..... | ..... | ..... | ..... | |
| 31 | ..... | eL | 0 50 00 | ..... | ..... | ..... | ..... | |
| | | L | 0 55 00 | 24 | ..... | ..... | ..... | |
| | | F | 1 40 00 | ..... | ..... | ..... | ..... | |
| 31 | ..... | P? | 3 35 35 | ..... | ..... | ..... | 8,430? | |
| | | S | 3 45 17 | ..... | ..... | ..... | ..... | |
| | | L | 3 57 00 | ..... | ..... | ..... | ..... | |
| | | F | 4 40 00 | ..... | ..... | ..... | ..... | |

TABLE 2.—*Instrumental reports, July, 1917*—Continued.

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| **District of Columbia. *Washington. Georgetown University.*** | | | | | | | | |
| **F. A. Tondorf, S. J.** | | | | | | | | |
| Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite. | | | | | | | | |
| Instruments: Wiechert 200 kg. astatic horizontal pendulums, 80 kg. vertical. | | | | | | | | |
| Instrumental constants: | | | | $V$ | $T_0$ | $\epsilon$ | | |
| | | | | E 165 | 5.4 | 0 | | |
| | | | | N 143 | 5.2 | 0 | | |
| | | | | *Z 80* | *3.0* | *0* | | |
| 1917. | | | *H. m. s.* | *Sec.* | $\mu$ | $\mu$ | *km.* | |
| July 4 | ..... | $e_E$ | 0 57 13 | ..... | ..... | ..... | ..... | Microseisms present. No distinct maximum. |
| | | $e_N$ | 0 57 21 | ..... | ..... | ..... | ..... | |
| | | eL | 1 07 13 | ..... | ..... | ..... | ..... | |
| | | L | 1 31 31 | ..... | ..... | ..... | ..... | |
| | | F | 2 33 00 | ..... | ..... | ..... | ..... | |
| 13 | ..... | eP | 5 19 05 | ..... | ..... | ..... | ..... | |
| | | $S_E$ | 5 22 52 | ..... | ..... | ..... | ..... | |
| | | $S_N$ | 5 22 54 | ..... | ..... | ..... | ..... | |
| | | eL | 5 23 06 | ..... | ..... | ..... | ..... | |
| | | F | 6 10 00 | ..... | ..... | ..... | ..... | |
| 14 | ..... | $e_N$ | 21 31 34 | ..... | ..... | ..... | ..... | Microseisms present. All phases doubtful. |
| | | $e_E$ | 21 31 36 | ..... | ..... | ..... | ..... | |
| | | S | 21 43 04 | ..... | ..... | ..... | ..... | |
| | | $eL_E$ | 21 50 04 | ..... | ..... | ..... | ..... | |
| | | $eL_N$ | 21 50 09 | ..... | ..... | ..... | ..... | |
| | | F | 22 15 00 | ..... | ..... | ..... | ..... | |
| 25 | ..... | eP | 3 38 18 | ..... | ..... | ..... | ..... | Microseisms present. |
| | | $S_N$ | 3 36 31 | ..... | ..... | ..... | ..... | |
| | | $S_E$ | 3 36 37 | ..... | ..... | ..... | ..... | |
| | | eL | 3 49 00 | ..... | ..... | ..... | ..... | |
| | | F | 4 45 00 | ..... | ..... | ..... | ..... | |
| | | VERTICAL. | | | | | | |
| | | *e* | *3 28 57* | ..... | ..... | ..... | ..... | S not discernible. |
| | | *eL* | *3 49 52* | ..... | ..... | ..... | ..... | |
| | | *L* | *3 51 52* | *30* | ..... | ..... | ..... | |
| | | *F* | *4 11 00* | ..... | ..... | ..... | ..... | |
| 25 | ..... | e | 22 42 43 | ..... | ..... | ..... | ..... | Very difficult to interpret. All phases doubtful. |
| | | eS | 22 50 17 | ..... | ..... | ..... | ..... | |
| | | eL | 23 03 17 | ..... | ..... | ..... | ..... | |
| | | F | 23 40 00 | ..... | ..... | ..... | ..... | |
| 27 | ..... | iP | 1 06 11 | ..... | ..... | ..... | ..... | |
| | | iS | 1 10 02 | ..... | ..... | ..... | ..... | |
| | | eL | 1 11 48 | ..... | ..... | ..... | ..... | |
| | | $M_N$ | 1 16 52 | 10 | ..... | *1950 | ..... | |
| | | $M_E$ | 1 17 00 | 9 | *3720 | ..... | ..... | F lost in succeeding quake. |
| | | VERTICAL. | | | | | | |
| | | *P* | *1 06 15* | ..... | ..... | ..... | ..... | |
| | | *S* | *1 10 16* | ..... | ..... | ..... | ..... | |
| | | *eL* | *1 12 18* | ..... | ..... | ..... | ..... | |
| | | *F* | *2 35* .. | ..... | ..... | ..... | ..... | |
| 27 | ..... | eP | 3 02 46 | ..... | ..... | ..... | ..... | No distinct maximum. |
| | | iS | 3 12 01 | ..... | ..... | ..... | ..... | |
| | | L | 3 17 00 | 11 | ..... | ..... | ..... | |
| | | F | 4 00 .. | ..... | ..... | ..... | ..... | |
| | | VERTICAL. | | | | | | |
| | | *eP* | *3 02 51* | ..... | ..... | ..... | ..... | |
| | | *S* | *3 12 09* | ..... | ..... | ..... | ..... | |
| | | *L* | *3 33 30* | *24* | ..... | ..... | ..... | |
| | | *F* | *4 00* .. | ..... | ..... | ..... | ..... | |
| 27 | ..... | $eP_N$ | 16 20 11 | ..... | ..... | ..... | ..... | No distinct maximum. |
| | | $eP_E$ | 16 20 13 | ..... | ..... | ..... | ..... | |
| | | $S_N$ | 16 24 09 | ..... | ..... | ..... | ..... | |
| | | $S_E$ | 16 24 13 | ..... | ..... | ..... | ..... | |
| | | $eL_N$ | 16 25 00 | 17 | ..... | ..... | ..... | |
| | | $eL_E$ | 16 25 12 | 17 | ..... | ..... | ..... | |
| | | F | 17 14 .. | ..... | ..... | ..... | ..... | |
| 29 | ..... | e | 14 44 49 | ..... | ..... | ..... | ..... | |
| | | $L_N$ | 15 23 30 | ..... | ..... | ..... | ..... | |
| | | $L_E$ | 15 24 48 | ..... | ..... | ..... | ..... | |
| | | F | 16 01 .. | ..... | ..... | ..... | ..... | |
| 29 | ..... | $e_N$ | 22 11 42 | ..... | ..... | ..... | ..... | e possibly sooner. |
| | | $e_E$ | 22 12 00 | ..... | ..... | ..... | ..... | Microseisms present. |
| | | $S_E$ | 22 15 06 | ..... | ..... | ..... | ..... | |
| | | $S_N$ | 22 15 08 | ..... | ..... | ..... | ..... | |
| | | eL? | 22 16 18 | ..... | ..... | ..... | ..... | F lost in changing |
| | | L | 22 25 00 | ..... | ..... | ..... | ..... | |
| 30 | | F | 1 .. .. | 13 | ..... | ..... | ..... | |
| 30 | ..... | e | 12 29 24 | ..... | ..... | ..... | ..... | Microseisms present. |
| | | L | 13 08 .. / 13 20 .. | ..... | ..... | ..... | ..... | F? |

* Trace amplitude.

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| **District of Columbia. *Washington. Georgetown University*—Contd.** | | | | | | | | |
| 1917. | | | *H. m. s.* | *Sec.* | $\mu$ | $\mu$ | *km.* | |
| July 31 | ..... | $e_E$ | 0 13 24 | ..... | ..... | ..... | ..... | $e_N$ and $S_N$ not discernible. |
| | | $eS_E$? | 0 20 44 | ..... | ..... | ..... | ..... | |
| | | eL | 0 50 42 | ..... | ..... | ..... | ..... | |
| | | $L_E$ | 0 56 08 | 24 | ..... | ..... | ..... | |
| | | $L_N$ | 1 01 .. | 30 | ..... | ..... | ..... | |
| | | F | 1 30 .. | ..... | ..... | ..... | ..... | |
| 31 | ..... | $eP_E$ | 3 36 04 | ..... | ..... | ..... | ..... | |
| | | $eP_N$ | 3 36 07 | ..... | ..... | ..... | ..... | |
| | | $S_E$ | 3 45 38 | ..... | ..... | ..... | ..... | |
| | | $S_N$ | 3 46 07 | ..... | ..... | ..... | ..... | |
| | | eL? | 3 51 15 | ..... | ..... | ..... | ..... | |
| | | F | 4 40 .. | ..... | ..... | ..... | ..... | |
| **Colorado. *Denver. Sacred Heart College.* Earthquake Station.** | | | | | | | | |
| **A. W. Forstall, S. J.** | | | | | | | | |
| Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation, 1,655 meters. | | | | | | | | |
| Instrument: Wiechert 80 kg., astatic, horizontal pendulum. | | | | | | | | |
| 1917. | | | *H. m. s.* | *Sec.* | $\mu$ | $\mu$ | *km.* | |
| July 27 | ..... | $P_N$ | 1 14 00 | ..... | ..... | ..... | ..... | Chilean quake. Good record but P and S do not appear on E-W component. E-W record much less satisfactory than N-S. |
| | | $S_N$ | 1 18 00 | ..... | ..... | ..... | ..... | |
| | | $L_N$ | 1 23 00 | 15–20 | ..... | *1,500 | ..... | |
| | | $L_E$ | 1 25 00 | 10–12 | *1,000 | ..... | ..... | |
| | | $M_N$ | 1 27 00 | 22 | ..... | *2,500 | ..... | |
| | | $M_E$ | 1 27 00 | 21 | *1,200 | ..... | ..... | |
| | | $C_E$ | 1 28 00 | ..... | ..... | ..... | ..... | |
| | | $C_N$ | 1 29 00 | 8 | ..... | ..... | ..... | |
| | | $F_E$ | 1 32 00 | ..... | ..... | ..... | ..... | |
| | | $F_N$ | 1 37 00 | ..... | ..... | ..... | ..... | |

* Trace amplitude.

**Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neuman.**

Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee of the British Association.

| Instrumental constant.. | $T_0$ |
|---|---|
| | 18.5 |

(Report for July, 1917, not received.)

**Kansas. *Lawrence. University of Kansas.* Department of Physics and Astronomy. F. E. Kester.**

Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters.

Instrument: Wiechert.

| Instrumental constants.. | $V$ | $T_0$ | $\epsilon$ |
|---|---|---|---|
| E | 177 | 3.4 | 4.1 |
| N | 205 | 3.4 | 4.1 |

(Report for July, 1917, not received.)

**Maryland. *Cheltenham. Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell.**

Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

| Instrumental constants.. | $V$ | $T_0$ |
|---|---|---|
| E | 10 | 33 |
| N | 10 | 25 |

| 1917. | | | *H. m. s.* | *Sec.* | $\mu$ | $\mu$ | *km.* |
|---|---|---|---|---|---|---|---|
| July 25 | ..... | $e_N$ | 2 42 38 | ..... | ..... | ..... | ..... |
| | | $e_E$ | 2 43 29 | ..... | ..... | ..... | ..... |
| | | $eL_E$ | 2 49 22 | 16 | ..... | ..... | ..... |
| | | $eL_N$ | 2 49 36 | 16 | ..... | ..... | ..... |
| | | $M_E$ | 2 53 28 | 14 | 10 | ..... | ..... |
| | | $M_N$ | 2 54 39 | 12 | ..... | 20 | ..... |
| | | C | 2 55 00 | ..... | ..... | ..... | ..... |
| | | F | 3 07 00 | ..... | ..... | ..... | ..... |

TABLE 2.—*Instrumental reports, July, 1917*—Continued.

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. ° | Remarks. |
|---|---|---|---|---|---|---|---|---|
| **Maryland. *Cheltenham. Magnetic Observatory*—Continued.** | | | | | | | | |
| 1917. | | | *H. m. s.* | *Sec.* | μ | μ | *km.* | |
| July 27 | ..... | P..... | 1 06 12 | ..... | ..... | ..... | ..... | |
| | | S..... | 1 10 00 | 3 | ..... | ..... | ..... | |
| | | $eL_E$... | 1 12 09 | 18 | ..... | ..... | ..... | |
| | | $M_E$... | 1 10 32 | ..... | 980 | ..... | ..... | |
| | | $M_N$... | 1 18 53 | 14 | ..... | 260 | ..... | |
| | | $M_E$... | 1 19 10 | 25 | 300 | ..... | ..... | |
| | | C..... | 1 47 00 | ..... | ..... | ..... | ..... | |
| | | F..... | 2 20 00 | ..... | ..... | ..... | ..... | |
| 27 | ..... | $eP_E$... | 3 02 38 | ..... | ..... | ..... | ..... | No long waves on E-W. |
| | | $eP_N$... | 3 02 40 | ..... | ..... | ..... | ..... | |
| | | $S_E$..... | 3 11 52 | ..... | ..... | ..... | ..... | |
| | | $S_N$..... | 3 11 54 | ..... | ..... | ..... | ..... | |
| | | $eL_N$... | 3 33 00 | 24 | ..... | ..... | ..... | |
| | | $M_N$... | 3 35 36 | 24 | ..... | 20 | ..... | |
| | | C..... | 3 41 00 | ..... | ..... | ..... | ..... | |
| | | F..... | 4 00 00 | ..... | ..... | ..... | ..... | |
| 29 | ..... | $eP_N$... | 22 13 50 | ..... | ..... | ..... | ..... | Phases indefinite. |
| | | $eP_E$... | 22 13 54 | ..... | ..... | ..... | ..... | |
| | | $eS_N$... | 22 23 35 | ..... | ..... | ..... | ..... | |
| | | $eS_E$... | 22 23 56 | ..... | ..... | ..... | ..... | |
| | | $eL_N$... | 22 49 00 | 18 | ..... | ..... | ..... | |
| | | $eL_E$... | 22 55 00 | 18 | ..... | ..... | ..... | |
| | | $M_E$... | 23 03 22 | ..... | 140 | ..... | ..... | |
| | | $M_N$... | 23 05 36 | ..... | ..... | 20 | ..... | |
| | | C..... | 23 21 00 | ..... | ..... | ..... | ..... | |
| 30 | | F..... | 0 14 00 | ..... | ..... | ..... | ..... | |
| 31 | ..... | e..... | 0 54 00 | ..... | ..... | ..... | ..... | Phases on N-S not defined, record barely discernible on E-W. |
| | | $M_N$... | 1 04 00 | ..... | ..... | 10 | ..... | |
| | | F..... | 1 15 00 | ..... | ..... | ..... | ..... | |
| **Massachusetts. *Cambridge. Harvard University. Seismographic Station.*** J. B. Woodworth. | | | | | | | | |
| Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial sand over clay. | | | | | | | | |
| Instruments: Two Bosch-Omori 100 kg. horizontal pendulums. Mechanical registration. | | | | | | | | |
| Instrumental constants. | | | | V / $T_0$ / ε | | | | |
| | | | | E 80 23 0 | | | | |
| | | | | N 50 25 4:1 | | | | |
| 1917. | | | *H. m. s.* | *Sec.* | μ | μ | *km.* | |
| July 1 | ..... | *O?*.... | *13 28 50* | ..... | ..... | ..... | 3,000? | |
| | | $eP_N$... | 13 34 47 | ..... | ..... | ..... | ..... | |
| | | $S_N$..... | 13 39 30 | ..... | ..... | ..... | ..... | |
| | | $S_E$..... | 13 39 54 | 6 | ..... | ..... | ..... | |
| | | $eL_N$... | 13 42 24 | 6-10 | ..... | ..... | ..... | Followed by periods of 8 seconds. |
| | | F..... | 14 03 00 | ..... | ..... | ..... | ..... | |
| 4 | ..... | *O?*.... | *0 49 01* | ..... | ..... | ..... | 4,850 | |
| | | $eP_E$... | 0 57 11 | ..... | ..... | ..... | ..... | |
| | | $S_E$..... | 1 03 53 | 6 | ..... | ..... | ..... | |
| | | $e_E$..... | 1 11 02 | ..... | ..... | ..... | ..... | |
| | | $e_E$..... | 1 13 11 | ..... | ..... | ..... | ..... | |
| | | $L_E$... | 1 27 42 | 42-50 | ..... | ..... | ..... | |
| | | $L_E$... | 1 33 27 | 30 | ..... | ..... | ..... | |
| | | $L_E$... | 1 35 53 | 25 | ..... | ..... | ..... | |
| | | $L_E$... | 1 38 09 | 25 | ..... | ..... | ..... | |
| | | F..... | 2 54 00 | ..... | ..... | ..... | ..... | |
| 4 | ..... | $e_E$..... | 6 14 08 | ..... | ..... | ..... | ..... | *O* at 5h plus. Amplitude very small. |
| | | $eL_E$... | 6 37 01 | 20 | ..... | ..... | ..... | |
| | | $L_E$..... | 6 38 56 | ..... | ..... | ..... | ..... | |
| | | F..... | 7 20 00 | ..... | ..... | ..... | ..... | |
| 10 | ..... | $L_E$.... | {18 20 22<br>18 31 38} | 20 | ..... | ..... | ..... | |
| 11 | ..... | *O?*.... | *22 45 00* | ..... | ..... | ..... | 12,100 | |
| | | $S_E$..... | 23 09 45 | 7 | ..... | ..... | ..... | |
| | | e..... | 23 28 27 | 14 | ..... | ..... | ..... | |
| | | e..... | 23 33 09 | 14 | ..... | ..... | ..... | |
| | | $eL_E$... | 23 34 45 | 30 | ..... | ..... | ..... | |
| | | $L_E$..... | 23 38 51 | 20 | ..... | ..... | ..... | |
| 12 | | F..... | 0 11 00 | ..... | ..... | ..... | ..... | |
| 12 | ..... | $L_E$.... | 12 43 02 | 24 | ..... | ..... | ..... | |
| | | $L_E$.... | 12 47 13 | 20 | ..... | ..... | ..... | |
| | | $L_E$.... | 12 58 51 | 16 | ..... | ..... | ..... | Record changed between 13h, 10m and 13h, 25m. |
| | | F..... | 14 14 00 | ..... | ..... | ..... | ..... | |
| 13 | ..... | *O*..... | *5 15 02* | ..... | ..... | ..... | 2,220 | |
| | | $P_N$..... | 5 19 39 | ..... | ..... | ..... | ..... | |
| | | $S_E$..... | 5 23 21 | 6 | ..... | ..... | ..... | |
| | | $eL_E$... | 5 24 35 | 21-16 | ..... | ..... | ..... | |
| | | F..... | 5 45 00 | ..... | ..... | ..... | ..... | |

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| **Massachusetts. *Cambridge. Harvard University*—Continued.** | | | | | | | | |
| 1917. | | | *H. m. s.* | *Sec.* | μ | μ | *km.* | |
| July 15 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | E-W component ran down at 0h 50m; in commission at 15h 22m. |
| 25 | ..... | *O*..... | *3 19 02* | ..... | ..... | ..... | 6,300 | Some uncertainty as to times by E-W component. |
| | | $P_E$?... | 3 28 38 | 3 | ..... | ..... | ..... | |
| | | $P_N$..... | 3 28 50 | ..... | ..... | ..... | ..... | |
| | | $S_E$..... | 3 36 22 | ..... | ..... | ..... | ..... | |
| | | $S_N$..... | 3 36 48 | 6 | ..... | ..... | ..... | |
| | | $i_E$..... | 3 40 12 | 10 | ..... | ..... | ..... | |
| | | $eL_N$... | 3 48 21 | ..... | ..... | ..... | ..... | |
| | | $eL_E$... | 3 49 00 | 20 | ..... | ..... | ..... | |
| | | $M_E$?... | 3 53 27 | 20 | ..... | ..... | ..... | |
| | | $F_E$..... | 4 52 00 | ..... | ..... | ..... | ..... | |
| 25 | ..... | *O?*.... | *22 32 09* | ..... | ..... | ..... | 6,470 | |
| | | $P_N$..... | 22 42 22 | ..... | ..... | ..... | ..... | |
| | | $S_N$..... | 22 50 37 | 6 | ..... | ..... | ..... | |
| | | $e_N$..... | 23 01 14 | 10 | ..... | ..... | ..... | |
| | | $L_N$..... | 23 04 37 | 23 | ..... | ..... | ..... | |
| | | $L_N$..... | 23 07 50 | 18 | ..... | ..... | ..... | |
| 26 | ..... | F..... | 0 02 00 | ..... | ..... | ..... | ..... | |
| 27 | ..... | *O*..... | *1 00 50* | ..... | ..... | ..... | 2,690 | |
| | | $P_E$..... | 1 06 17 | ..... | ..... | ..... | ..... | |
| | | $P_N$..... | 1 06 30 | 10 | ..... | ..... | ..... | |
| | | $S_E$..... | 1 10 27 | ..... | ..... | ..... | ..... | |
| | | $S_N$..... | 1 10 42 | ..... | ..... | ..... | ..... | |
| | | $L_N$..... | 1 14 24 | ..... | ..... | ..... | ..... | F lost in succeeding quake. |
| 27 | ..... | *O*..... | *2 51 22* | ..... | ..... | ..... | 7,870 | |
| | | $P_N$..... | 3 03 00 | ..... | ..... | ..... | ..... | |
| | | $P_E$..... | 3 03 07 | ..... | ..... | ..... | ..... | |
| | | $S_N$..... | 3 12 13 | ..... | ..... | ..... | ..... | |
| | | $S_E$..... | 3 12 25 | ..... | ..... | ..... | ..... | |
| | | $eL_E$... | 3 26 01 | ..... | ..... | ..... | ..... | |
| | | L..... | 3 37 27 | ..... | ..... | ..... | ..... | |
| | | $L_{rep}$... | 5 37 35 | 20 | ..... | ..... | ..... | |
| | | F..... | 4 41 31 | ..... | ..... | ..... | ..... | |
| 27 | ..... | *O*..... | *16 14 46* | ..... | ..... | ..... | 2,640 | |
| | | $P_N$..... | 16 20 08 | ..... | ..... | ..... | ..... | |
| | | $P_E$..... | 16 20 47 | ..... | ..... | ..... | ..... | |
| | | S..... | 16 24 24 | ..... | ..... | ..... | ..... | |
| | | $eL_N$... | 16 26 06 | ..... | ..... | ..... | ..... | |
| | | $eL_E$... | 16 27 34 | 15 | ..... | ..... | ..... | |
| | | $C_E$..... | 16 34 28 | ..... | ..... | ..... | ..... | |
| | | F..... | 16 50 .. | ..... | ..... | ..... | ..... | |
| 28 | ..... | $e_E$..... | 0 41 11 | ..... | ..... | ..... | ..... | |
| | | $L_E$..... | 0 42 59 | 20 | ..... | ..... | ..... | |
| | | $L_E$..... | 0 47 25 | 24 | ..... | ..... | ..... | |
| | | F..... | 1 .. .. | ..... | ..... | ..... | ..... | |
| 28 | ..... | $e_E$?... | 1 26 55 | ..... | ..... | ..... | ..... | |
| | | $S_E$?... | 1 30 04 | 6 | ..... | ..... | ..... | |
| | | $L_E$?... | 1 35 16 | 20 | ..... | ..... | ..... | |
| | | e..... | 1 43 31 | 6 | ..... | ..... | ..... | |
| | | $L_E$..... | 1 46 33 | 16 | ..... | ..... | ..... | |
| | | F..... | 2 02 .. | ..... | ..... | ..... | ..... | |
| 29 | ..... | $L_N$..... | 6 22 41 | 15 | ..... | ..... | ..... | |
| | | F..... | 6 52 .. | ..... | ..... | ..... | ..... | |
| 29 | ..... | $e_E$..... | 14 56 07 | ..... | ..... | ..... | ..... | *O* at 14h+, N-S run down at 13h 9m. Started at 15h 18m. Records changed at 15h 12m. $L_N$ at 15h 18m 1s, period 32 sec. |
| | | $e_E$..... | 15 05 35 | ..... | ..... | ..... | ..... | |
| | | $L_E$..... | 15 27 51 | 20 | ..... | ..... | ..... | |
| | | F..... | 15 40 .. | ..... | ..... | ..... | ..... | |
| 29 | ..... | $e_N$..... | 22 14 02 | ..... | ..... | ..... | ..... | May be artificial disturbance. |
| | | $S_N$?... | 22 14 06 | 9 | ..... | ..... | ..... | |
| | | $L_N$?... | {22 24 10<br>22 31 32} | 10-12 | ..... | ..... | ..... | |
| 30 | | F..... | 1 45 .. | ..... | ..... | ..... | ..... | |
| 30 | ..... | $L_N$..... | 5 33 17 | 20 | ..... | ..... | ..... | Artificial disturbance? |
| | | $L_N$..... | 5 44 24 | 16 | ..... | ..... | ..... | |
| | | $F_N$..... | 5 54 20 | ..... | ..... | ..... | ..... | |
| 30 | ..... | $L_N$..... | 9 22 16 | ..... | ..... | ..... | ..... | Very faint record. Possibly artificial disturbance. |
| | | F..... | 9 32 06 | ..... | ..... | ..... | ..... | |
| 30 | ..... | $L_N$..... | 12 31 17 | 14 | ..... | ..... | ..... | Artificial disturbance? Changing records from 13h 24m to 13h 30m. Amplitude increases. |
| | | $L_N$..... | 12 33 03 | 16 | ..... | ..... | ..... | |
| | | $L_N$..... | 12 57 04 | ..... | ..... | ..... | ..... | |
| | | $L_N$..... | 13 06 58 | 14-16 | ..... | ..... | ..... | |
| | | $L_N$..... | 13 07 34 | ..... | ..... | ..... | ..... | |
| | | $L_N$..... | 13 14 .. | ..... | ..... | ..... | ..... | |
| | | $L_N$..... | 13 38 20 | 16 | ..... | ..... | ..... | |
| | | F..... | 17 10 .. | ..... | ..... | ..... | ..... | |

TABLE 2.—*Instrumental reports, July, 1917*—Continued.

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| **Massachusetts. *Cambridge. Harvard University*—Continued.** | | | | | | | | |
| 1917. July 31 | ..... | $S_N$?... | *H. m. s.* 0 23 51 | *Sec.* 7 | μ ..... | μ ..... | *km.* ..... | |
| | | $eL_N$?.. | 0 51 17 | 30 | ..... | ..... | ..... | |
| | | L..... | 0 51 29 | 24 | ..... | ..... | ..... | |
| | | L..... | 0 55 11 | 24 | ..... | ..... | ..... | |
| | | L..... | 1 02 51 | 15 | ..... | ..... | ..... | |
| | | F..... | 1 38 43 | ..... | ..... | ..... | ..... | |
| 31 | ..... | *O*..... | *3 23 58* | ..... | ..... | ..... | 8,710 | Masked by microseisms. |
| | | $P_N$.... | 3 35 56 | ..... | ..... | ..... | ..... | |
| | | $P_E$.... | 3 36 03 | 2 | ..... | ..... | ..... | |
| | | $S_N$.... | 3 45 52 | 10 | ..... | ..... | ..... | |
| | | $S_E$.... | 3 46 05 | 6 | ..... | ..... | ..... | |
| | | $i_E$..... | 3 48 50 | *0 | ..... | ..... | ..... | |
| | | $i_N$..... | 3 49 32 | ..... | ..... | ..... | ..... | |
| | | $eL_N$... | 3 52 34 | ..... | ..... | ..... | ..... | |
| | | $eL_E$... | 3 52 53 | 16 | ..... | ..... | ..... | |
| | | F..... | 4 48 17 | ..... | ..... | ..... | ..... | |

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instrument: Wiechert, 80 kg. astatic, horizontal pendulum.

| Instrumental constants.. | *V* | $T_0$ | *e* |
|---|---|---|---|
| | 80 | 7 | 5:1 |

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| 1917. July 25 | $I_u$..... | iS?.... | *H. m. s.* 21 35 00 | *Sec.* ..... | μ ..... | μ ..... | *km.* ..... | |
| | | F..... | 22 00 .. | ..... | ..... | ..... | ..... | |
| 27 | $III_r$... | eP..... | 0 07 00 | ..... | ..... | ..... | 2,500 | |
| | | S..... | 0 12 00 | ..... | ..... | ..... | ..... | |
| | | L..... | 0 14 30 | ..... | ..... | ..... | ..... | |
| | | $M_N$.... | 0 15 00 | 24 | ..... | 10 | ..... | |
| | | F..... | 1 22 00 | ..... | ..... | ..... | ..... | |
| 27 | $III_r$... | $iP_E$.... | 2 03 00 | ..... | ..... | ..... | 4,400 | |
| | | $S_E$?.... | 2 11 30 | ..... | ..... | ..... | ..... | |
| | | F..... | 2 27 00 | ..... | ..... | ..... | ..... | |
| 27 | $II_r$..... | e..... | 7 45 00 | ..... | ..... | ..... | ..... | |
| | | F..... | 8 00 00 | ..... | ..... | ..... | ..... | |
| 29 | $I_u$..... | e..... | 22 19 00 | ..... | ..... | ..... | ..... | |
| | | F..... | 22 25 00 | ..... | ..... | ..... | ..... | |
| 31 | $I_u$..... | e..... | 0 53 00 | ..... | ..... | ..... | ..... | |
| | | F..... | 1 36 00 | ..... | ..... | ..... | ..... | |
| 31 | $I_u$..... | e..... | 1 44 00 | ..... | ..... | ..... | ..... | |
| | | F..... | 2 04 00 | ..... | ..... | ..... | ..... | |

New York. *Buffalo. Canisius College.* John A. Curtin, S. J.

Lat., 42° 53′ 02″ N.; long., 78° 52′ 40″ W. Elevation, 190.5 meters.

Instrument: Wiechert, 80 kg. horizontal.

| Instrumental constants.. | *V* | $T_0$ | *e* |
|---|---|---|---|
| | 80 | 7 | 5:1 |

(Report for July, 1917, not received.)

New York. *Fordham. Fordham University.* Daniel H. Sullivan, S. J.

Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.

Instrument: Wiechert, 80 kg.

| Instrumental constants.. | | *V* | $T_0$ | *e* |
|---|---|---|---|---|
| | E | 72 | 6.6 | 1.5:1 |
| | N | 72 | 7.1 | 3.8:1 |

(Report for July, 1917, not received.)

New York. *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori, 25 kg., horizontal pendulums. Mechanical registration.

| Instrumental constants.. | | *V* | $T_0$ | *e* |
|---|---|---|---|---|
| | E | 13 | 22 | 4:1 |
| | N | 14 | 25 | 4:1 |

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| 1917. July 1 | ..... | $e_N$..... | *H. m. s.* 13 37 03 | *Sec.* 3 | μ ..... | μ ..... | *km.* ..... | |
| | | $e_E$..... | 13 37 06 | 4 | ..... | ..... | ..... | |
| | | $L_E$?... | 13 39 39 | 9 | ..... | ..... | ..... | |
| | | $L_N$?... | 13 40 18 | 10 | ..... | ..... | ..... | |
| | | $F_E$.... | 13 43 30 | ..... | ..... | ..... | ..... | |
| | | $F_N$.... | 13 44 00 | ..... | ..... | ..... | ..... | |

**New York. *Ithaca. Cornell University*—Continued.**

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| 1917. July 4 | ..... | $e_E$..... | *H. m. s.* 1 11 40 | *Sec.* 9 | μ ..... | μ ..... | *km.* ..... | |
| | | $e_N$..... | 1 11 41 | 11 | ..... | ..... | ..... | |
| | | $eL_E$... | 1 27 18 | 36 | ..... | ..... | ..... | |
| | | $eL_N$... | 1 31 13 | 24 | ..... | ..... | ..... | |
| | | $F_E$.... | 2 09 00 | ..... | ..... | ..... | ..... | |
| | | $F_N$.... | 2 17 00 | ..... | ..... | ..... | ..... | |
| 13 | ..... | $e_N$..... | 5 19 20 | 4 | ..... | ..... | ..... | |
| | | $e_E$..... | 5 22 11 | 4 | ..... | ..... | ..... | |
| | | $e_E$..... | 5 23 12 | 4 | ..... | ..... | ..... | |
| | | $e_N$..... | 5 23 22 | 3 | ..... | ..... | ..... | |
| | | $F_N$.... | 5 30 00 | ..... | ..... | ..... | ..... | |
| | | $F_E$.... | 5 30 30 | ..... | ..... | ..... | ..... | |
| 25 | ..... | $e_N$..... | 3 35 28 | 6 | ..... | ..... | ..... | |
| | | $eL_N$... | 3 44 32 | 36 | ..... | ..... | ..... | |
| | | $F_N$.... | 4 28 00 | ..... | ..... | ..... | ..... | |
| 27 | ..... | $P_N$.... | 1 05 55 | 4 | ..... | ..... | ..... | |
| | | $S_N$.... | 1 10 21 | 8 | ..... | ..... | ..... | |
| | | $L_N$.... | 1 12 13 | 16 | ..... | ..... | ..... | |
| | | $M_N$.... | 1 13 50 | 19 | ..... | *2,200 | ..... | |
| | | $L_N$.... | 1 16 37 | 14 | ..... | ..... | ..... | |
| | | $M_N$.... | 1 20 03 | 12 | ..... | *2,800 | ..... | |
| | | $F_N$.... | 2 45 00 | ..... | ..... | ..... | ..... | |
| 27 | ..... | $eP_N$... | 3 02 27 | 4 | ..... | ..... | ..... | |
| | | $S_N$.... | 3 12 01 | 9 | ..... | ..... | ..... | |
| | | $L_N$.... | 3 28 08 | 28 | ..... | ..... | ..... | |
| | | $F_N$.... | 4 13 00 | ..... | ..... | ..... | ..... | |
| 27 | ..... | $e_N$..... | 16 24 29 | 7 | ..... | ..... | ..... | |
| | | $L_N$.... | 16 26 20 | 24 | ..... | ..... | ..... | |
| | | $F_N$.... | 16 56 00 | ..... | ..... | ..... | ..... | |
| 29 | ..... | $L_N$.... | 22 51 43 | 32 | ..... | ..... | ..... | Seismograph not recording during early phases. |
| | | $F_N$.... | 24 19 00 | ..... | ..... | ..... | ..... | |

* Trace amplitude.

Panama Canal Zone. *Balboa Heights.* Isthmian Canal Commission.

Lat., 8° 57′ 39″ N.; long., 79° 33′ 29″ W. Elevation, 27.6 meters.

Instruments: Two Bosch-Omori, 100 kg.

| Instrumental constants.. | *V* | $T_0$ |
|---|---|---|
| | 10 | 20 |

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| 1917. July 1 | ..... | $M_E$.... | *H. m. s.* 0 24 17 | *Sec.* ..... | μ ..... | μ ..... | *km.* ..... | Distance and direction? |
| | | $M_N$.... | 0 25 18 | ..... | ..... | ..... | ..... | |
| 11 | ..... | $M_E$.... | 7 26 16 | ..... | *100 | ..... | ..... | Slight movement. |
| | | $M_N$.... | 7 26 16 | ..... | *200 | ..... | ..... | |
| 27 | ..... | $P_N$.... | 1 04 48 | ..... | ..... | ..... | 1,815 | Direction N? |
| | | $P_E$.... | 1 04 50 | ..... | ..... | ..... | ..... | |
| | | S..... | 1 07 46 | ..... | ..... | ..... | ..... | |
| | | $L_N$.... | 1 09 16 | ..... | ..... | ..... | ..... | |
| | | $L_E$.... | 1 09 24 | ..... | ..... | ..... | ..... | |
| | | $M_E$.... | 1 05 06 | ..... | *9,000 | ..... | ..... | |
| | | $M_N$.... | 1 07 56 | ..... | ..... | *10,000 | ..... | |
| | | $F_E$.... | 2 02 00 | ..... | ..... | ..... | ..... | |
| | | $F_N$.... | 2 06 00 | ..... | ..... | ..... | ..... | |
| 27 | ..... | $P_N$.... | 2 59 36 | ..... | ..... | ..... | 1,945 | Direction N? |
| | | $P_E$.... | 2 59 42 | ..... | ..... | ..... | ..... | |
| | | $L_N$.... | 3 05 31 | ..... | ..... | ..... | ..... | |
| | | $L_E$.... | 3 05 36 | ..... | ..... | ..... | ..... | |
| | | $M_N$.... | 3 05 54 | ..... | ..... | *1,500 | ..... | |
| | | $M_E$.... | 3 09 42 | ..... | *500 | ..... | ..... | |
| | | $F_E$.... | 3 57 00 | ..... | ..... | ..... | ..... | |
| | | $F_N$.... | 4 01 00 | ..... | ..... | ..... | ..... | |

* Trace amplitude.

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. L. Adams.

Lat., 18° 08′ 48″ N.; long., 65° 26′ 54″ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

| Instrumental constants.. | | *V* | $T_0$ |
|---|---|---|---|
| | E | 10 | 17.5 |
| | N | 10 | 18 |

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| 1917. July 13 | ..... | $eP_E$... | *H. m. s.* 5 14 25 | *Sec.* ..... | μ ..... | μ ..... | *km.* ..... | |
| | | $eS_E$.... | 5 14 48 | ..... | ..... | ..... | ..... | |
| | | $eS_N$... | 5 14 55 | ..... | ..... | ..... | ..... | |
| | | eL..... | 5 15 20 | 6 | ..... | ..... | ..... | |
| | | $M_N$.... | 5 15 43 | 5 | ..... | 100 | ..... | |
| | | $M_E$.... | 5 15 35 | ..... | 90 | ..... | ..... | |
| | | C..... | 5 17 00 | ..... | ..... | ..... | ..... | |
| | | F..... | 5 26 00 | ..... | ..... | ..... | ..... | |

TABLE 2.—*Instrumental reports, July, 1917*—Continued.

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| **Porto Rico. *Vieques. Magnetic Observatory*—Continued.** | | | | | | | | |
| 1917. July 27 | ..... | P..... | *H. m. s.* 1 02 02 | *Sec.* ..... | *μ* ..... | *μ* ..... | *km.* ..... | Both needles went off the sheet at 1h 03m 10s. Neither instrument was recording during what was probably the maximum part of the disturbance. |
| | | $eL_E$... | 1 02 20 | ..... | ..... | ..... | ..... | |
| | | $eL_N$... | 1 02 26 | ..... | 7,000 | 6,800 | ..... | |
| | | C..... | 1 11 00 | ..... | ..... | ..... | ..... | |
| | | F..... | 2 40 00 | ..... | ..... | ..... | ..... | |
| 27 | ..... | P..... | 16 16 02 | ..... | ..... | ..... | ..... | The end of the E-W record was confused by wind tremors. |
| | | S..... | 16 16 38 | ..... | ..... | ..... | ..... | |
| | | L..... | 16 16 54 | ..... | ..... | ..... | ..... | |
| | | $M_N$.... | 16 17 08 | 18 | ..... | 720 | ..... | |
| | | $M_E$.... | 16 17 26 | 15 | 920 | ..... | ..... | |
| | | C..... | 16 21 00 | ..... | ..... | ..... | ..... | |
| | | F..... | 16 26 00 | ..... | ..... | ..... | ..... | |
| 29 | ..... | $P_E$.... | 6 10 50 | ..... | ..... | ..... | ..... | Time of phases on E-W uncertain on account of time-marking device not working properly. |
| | | $P_N$.... | 6 10 52 | ..... | ..... | ..... | ..... | |
| | | $L_N$.... | 6 11 02 | ..... | ..... | ..... | ..... | |
| | | $L_E$.... | 6 11 06 | ..... | ..... | ..... | ..... | |
| | | $M_N$.... | 6 11 10 | ..... | ..... | 50 | ..... | |
| | | $M_E$.... | 6 11 25 | ..... | 70 | ..... | ..... | |
| | | C..... | 6 12 00 | ..... | ..... | ..... | ..... | |
| | | F..... | 6 18 00 | ..... | ..... | ..... | ..... | |
| Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw. | | | | | | | | |
| Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters. | | | | | | | | |
| Instruments: Two Bosch-Omori. Mechanical registration. | | | | | | | | |
| Instrumental constants. | | | | *V* | $T_0$ | | | |
| | | | | E 10 | 15 | | | |
| | | | | N 10 | 16 | | | |
| 1917. July 1 | ..... | S?..... | *H. m. s.* 13 38 20 | *Sec.* ..... | *μ* ..... | *μ* ..... | *km.* ..... | |
| | | L..... | 13 51 00 | ..... | ..... | ..... | ..... | |
| | | F..... | 14 00 .. | ..... | ..... | ..... | ..... | |
| 4 | ..... | L..... | 1 38 00 | ..... | ..... | ..... | ..... | |
| | | F..... | 2 15 .. | ..... | ..... | ..... | ..... | |
| 25 | ..... | P..... | 3 28 17 | ..... | ..... | ..... | 6,400 | |
| | | S..... | 3 36 15 | ..... | ..... | ..... | ..... | |
| | | L..... | 3 45 40 | ..... | ..... | ..... | ..... | |
| | | L..... | 3 50 00 | 20 | ..... | ..... | ..... | |
| | | F..... | 4 00 .. | ..... | ..... | ..... | ..... | |
| 25 | ..... | e..... | 22 45 12 | ..... | ..... | ..... | ..... | No phases discernible. |
| | | F..... | 23 15 .. | ..... | ..... | ..... | ..... | |
| 27 | ..... | P..... | 1 06 38 | ..... | ..... | ..... | 2,875 | |
| | | S..... | 1 11 12 | ..... | ..... | ..... | ..... | |
| | | L..... | 1 14 15 | ..... | ..... | ..... | ..... | |
| | | F..... | 2 30 .. | ..... | ..... | ..... | ..... | |
| 27 | ..... | P..... | 3 02 21 | ..... | ..... | ..... | 9,450 | |
| | | S..... | 3 12 54 | ..... | ..... | ..... | ..... | |
| | | L..... | 3 31 35 | ..... | ..... | ..... | ..... | |
| | | F..... | 4 00 .. | ..... | ..... | ..... | ..... | |
| 27 | ..... | e?..... | 16 27 15 | ..... | ..... | ..... | ..... | |
| | | L..... | 16 31 15 | ..... | ..... | ..... | ..... | |
| | | F..... | 17 00 .. | ..... | ..... | ..... | ..... | |
| 29 | ..... | eL..... | 15 12 30 | ..... | ..... | ..... | ..... | |
| | | L..... | 15 20 40 | 24 | ..... | ..... | ..... | |
| | | F..... | 15 40 .. | ..... | ..... | ..... | ..... | |
| 29 | ..... | e..... | 22 13 40 | ..... | ..... | ..... | ..... | |
| | | L..... | 22 32 00 | ..... | ..... | ..... | ..... | |
| | | L..... | 22 57 00 | 24 | ..... | ..... | ..... | |
| | | L..... | 23 02 00 | 20 | ..... | ..... | ..... | |
| 30 | ..... | F..... | 0 15 .. | ..... | ..... | ..... | ..... | |
| 31 | ..... | eL..... | 0 57 00 | ..... | ..... | ..... | ..... | |
| | | L..... | 1 01 00 | 20 | ..... | ..... | ..... | |
| | | F..... | 1 15 00 | ..... | ..... | ..... | ..... | |
| 31 | ..... | e..... | 3 38 50 | ..... | ..... | ..... | ..... | |
| | | S?..... | 3 44 56 | ..... | ..... | ..... | ..... | |
| | | L..... | 3 55 05 | ..... | ..... | ..... | ..... | |
| | | F..... | 4 00 .. | ..... | ..... | ..... | ..... | |

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake. Station. Otto Klotz. | | | | | | | | |
| Lat., 45° 23′ 38″ N.; long., 75h 42′ 57″ W. Elevation, 83 meters. | | | | | | | | |
| Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer 80kg. vertical seismograph. | | | | | | | | |
| Instrumental constants. | | | | *V* 120 | $T_0$ 26 | | | |
| 1917. July 1 | ..... | i..... | *H. m. s.* 13 36 59 | *Sec.* 2 | *μ* ..... | *μ* ..... | *km.* ..... | |
| | | i..... | 13 37 33 | 4 | ..... | ..... | ..... | |
| | | $L_E$.... | 13 48 00 | 24 | ..... | ..... | ..... | |
| | | F..... | 14 00 00 | ..... | ..... | ..... | ..... | |
| 4 | ..... | *O?*.... | *0 48 54* | ..... | ..... | ..... | 4,800? | |
| | | $eP_E$?.. | 0 57 06 | ..... | ..... | ..... | ..... | |
| | | $iP_N$?.. | 0 57 11 | 2 | ..... | ..... | ..... | |
| | | $iS_E$?... | 1 03 38 | ..... | ..... | ..... | ..... | |
| | | $iS_N$?... | 1 03 42 | ..... | ..... | ..... | ..... | |
| | | $eL_N$?.. | 1 11 .. | 14 | ..... | ..... | ..... | |
| | | $eL_E$?.. | 1 12 .. | 14 | ..... | ..... | ..... | |
| | | L..... | 1 25 .. | 40 | ..... | ..... | ..... | |
| | | L..... | 1 32 .. | 30 | ..... | ..... | ..... | |
| | | L..... | 1 38 .. | 20 | ..... | ..... | ..... | |
| | | L..... | 1 44 .. | 19 | ..... | ..... | ..... | |
| | | L..... | 1 49 .. | 15 | ..... | ..... | ..... | |
| | | L..... | 2 09 .. | 16 | ..... | ..... | ..... | |
| | | L..... | 2 22 .. | 16 | ..... | ..... | ..... | |
| | | F..... | 2 40 .. | ..... | ..... | ..... | ..... | |
| 4 | ..... | *O?*.... | *5 46 55* | ..... | ..... | ..... | 4,720? | |
| | | iP?.... | 5 55 04 | ..... | ..... | ..... | ..... | |
| | | iS?.... | 6 01 31 | ..... | ..... | ..... | ..... | |
| | | eL?... | 6 09 00 | 20 | ..... | ..... | ..... | |
| | | L..... | 6 32 .. | 32 | ..... | ..... | ..... | |
| | | L..... | 6 37 .. | 27 | ..... | ..... | ..... | |
| | | L..... | 6 42 .. | 20 | ..... | ..... | ..... | |
| | | L..... | 6 45 .. / 7 01 .. | 17–14 | ..... | ..... | ..... | |
| | | F..... | 7 10 .. | ..... | ..... | ..... | ..... | |
| 12 | ..... | eL..... | 12 41 24 | 20–25 | ..... | ..... | ..... | |
| | | L..... | 12 48 .. | 22 | ..... | ..... | ..... | |
| | | L..... | 13 00 .. | 18 | ..... | ..... | ..... | |
| | | F..... | 14 00 .. | ..... | ..... | ..... | ..... | |
| 13 | ..... | *O?*.... | *5 16 47* | ..... | ..... | ..... | 4,400? | |
| | | eP?... | 5 24 34 | ..... | ..... | ..... | ..... | |
| | | $iPR1_E$ | 5 25 41 | ..... | ..... | ..... | ..... | |
| | | $iPR2_E$ | 5 26 13 | ..... | ..... | ..... | ..... | |
| | | $eS_N$?.. | 5 30 27 | 8 | ..... | ..... | ..... | |
| | | $eS_E$?.. | 5 30 31 | ..... | ..... | ..... | ..... | |
| | | i..... | 5 30 50 | ..... | ..... | ..... | ..... | |
| | | eL..... | 5 34 12 | 14 | ..... | ..... | ..... | |
| | | L..... | 5 40 .. | 14 | ..... | ..... | ..... | |
| | | F..... | 6 00 .. | ..... | ..... | ..... | ..... | |
| 15 | ..... | $e_N$..... | 10 45 00 | 4 | ..... | ..... | ..... | |
| | | $e_N$..... | 10 47 24 | 4 | ..... | ..... | ..... | |
| | | $e_N$..... | 10 50 48 | 7 | ..... | ..... | ..... | |
| | | $e_N$..... | 10 54 32 | 6 | ..... | ..... | ..... | |
| | | $eL_N$... | 11 00 42 | 16 | ..... | ..... | ..... | |
| | | $L_N$.... | 11 05 .. / 11 33 .. | 20 | ..... | ..... | ..... | |
| | | F..... | 11 45 .. | ..... | ..... | ..... | ..... | |
| 25 | ..... | *O*..... | *3 19 12* | ..... | ..... | ..... | 5,660 | |
| | | iP..... | 3 28 22 | ..... | ..... | ..... | ..... | |
| | | iS..... | 3 35 40 | ..... | ..... | ..... | ..... | |
| | | eL..... | 3 44 18 | 8 | ..... | ..... | ..... | |
| | | L..... | 3 50 .. | 16 | ..... | ..... | ..... | |
| | | L..... | 4 10 .. | 13 | ..... | ..... | ..... | |
| | | F..... | 5 00 .. | ..... | ..... | ..... | ..... | |
| 25 | ..... | *O*..... | *22 52 54* | ..... | ..... | ..... | 5,710 | |
| | | iP..... | 22 42 07 | ..... | ..... | ..... | ..... | |
| | | iS..... | 22 49 28 | 6 | ..... | ..... | ..... | |
| | | eL..... | 22 58 04 | 8 | ..... | ..... | ..... | |
| | | L..... | 23 04 .. | 16 | ..... | ..... | ..... | |
| | | L..... | 23 14 .. | 7 | ..... | ..... | ..... | |
| | | L..... | 23 28 .. | 7 | ..... | ..... | ..... | |
| | | F..... | 24 00 .. | ..... | ..... | ..... | ..... | |
| 27 | ..... | *O*..... | *1 01 16* | ..... | ..... | ..... | 2,900 | |
| | | $eP_N$... | 1 07 02 | ..... | ..... | ..... | ..... | |
| | | $iP_N$... | 1 07 04 | ..... | ..... | ..... | ..... | |
| | | iS..... | 1 11 39 | 8 | ..... | ..... | ..... | |
| | | $eL_E$... | 1 13 30 | 20 | ..... | ..... | ..... | |
| | | $L_E$.... | 1 16 00 | 14 | ..... | ..... | ..... | |
| | | $M_N$.... | 1 22 42 | 12 | ..... | 190 | ..... | |
| | | L..... | 1 30 .. | 14 | ..... | ..... | ..... | |
| | | L..... | 1 55 .. | 12 | ..... | ..... | ..... | |
| | | L..... | 2 07 .. | 14 | ..... | ..... | ..... | |
| | | L..... | 2 38 .. | 12 | ..... | ..... | ..... | Merges into succeeding quake. |

TABLE 2.—*Instrumental reports, July, 1917*—Continued.

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| **Canada.** *Ottawa. Dominion Astronomical Observatory*—Continued. | | | | | | | | |
| 1917. July 27 | ..... | *O*..... | *H. m. s.* *2 51 33* | *Sec.* ..... | ..... | ..... | *km.* 8,550 | |
| | | iP..... | 3 03 23 | ..... | ..... | ..... | ..... | |
| | | iS..... | 3 13 11 | ..... | ..... | ..... | ..... | |
| | | eL..... | 3 30 00 | 24 | ..... | ..... | ..... | |
| | | L..... | 3 40 00 | 20 | ..... | ..... | ..... | |
| | | L..... | 3 55 00 | 17 | ..... | ..... | ..... | |
| | | L..... | 4 19 00 | 15 | ..... | ..... | ..... | |
| | | LR1?. | 5 11 00 | 18 | ..... | ..... | ..... | |
| | | L..... | 5 17 00 | 14 | ..... | ..... | ..... | |
| | | F..... | 6 00 00 | ..... | ..... | ..... | ..... | |
| 27 | ..... | *O*?.... | *16 13 40* | ..... | ..... | ..... | 3,550? | |
| | | P?..... | 16 20 24 | ..... | ..... | ..... | ..... | |
| | | S?..... | 16 25 44 | ..... | ..... | ..... | ..... | |
| | | eL..... | 16 28 00 | 17–18 | ..... | ..... | ..... | |
| | | L..... | 16 36 00 | 14 | ..... | ..... | ..... | |
| | | L..... | 16 53 00 | 13 | ..... | ..... | ..... | |
| | | L..... | 17 13 00 | 12 | ..... | ..... | ..... | |
| 28 | ..... | e?..... | 1 30 16 | ..... | ..... | ..... | ..... | |
| | | eL..... | 1 44 48 | 18 | ..... | ..... | ..... | |
| | | L..... | 1 53 00 | 12 | ..... | ..... | ..... | |
| | | F..... | 2 30 00 | ..... | ..... | ..... | ..... | |
| 29 | ..... | *O*?.... | *14 46 49* | ..... | ..... | ..... | 5,300? | |
| | | eP?.... | 14 55 36 | ..... | ..... | ..... | ..... | |
| | | $iP_E$... | 14 55 47 | ..... | ..... | ..... | ..... | |
| | | $S_N$.... | 15 02 33 | ..... | ..... | ..... | ..... | |
| | | eL?... | 15 11 12 | 12 | ..... | ..... | ..... | |
| | | L..... | 15 15 00 | 26–24 | ..... | ..... | ..... | |
| | | L..... | 15 24 00 | 24 | ..... | ..... | ..... | |
| | | L..... | 15 30 00 | 19 | ..... | ..... | ..... | |
| | | F..... | 16 10 00 | ..... | ..... | ..... | ..... | |
| 29 | ..... | P..... | 22 12 48 | ..... | ..... | ..... | ..... | No record from seismograph. Clock stopped. Record from "Deformation instrument." |
| | | i..... | 22 16 12 | ..... | ..... | ..... | ..... | |
| | | i..... | 22 25 12 | ..... | ..... | ..... | ..... | |
| | | i..... | 22 30 36 | ..... | ..... | ..... | ..... | |
| | | M..... | 22 57 48 | ..... | ..... | ..... | ..... | |
| | | M..... | 23 52 12 | ..... | ..... | ..... | ..... | |
| 30 | | F..... | 1 00 00 | ..... | ..... | ..... | ..... | |
| 31 | ..... | $e_N$..... | 0 20 00 | ..... | ..... | ..... | ..... | Record masked by microseisms. |
| | | $e_E$..... | 0 20 28 | ..... | ..... | ..... | ..... | |
| | | eL?... | 0 46 00 | 36 | ..... | ..... | ..... | |
| | | L..... | 0 53 00 | 24–20 | ..... | ..... | ..... | |
| | | L..... | 1 00 00 | 20 | ..... | ..... | ..... | |
| | | L..... | 1 05 00 | 14–18 | ..... | ..... | ..... | |
| | | L..... | 1 13 00 | 14 | ..... | ..... | ..... | |
| | | F..... | 1 40 00 | ..... | ..... | ..... | ..... | |
| 31 | ..... | *O*?.... | *3 24 11* | ..... | ..... | ..... | 8,000? | Record masked by microseisms. |
| | | iP?.... | 3 35 32 | 4 | ..... | ..... | ..... | |
| | | i..... | 3 39 10 | 2 | ..... | ..... | ..... | |
| | | iS?.... | 3 44 53 | 2 | ..... | ..... | ..... | |
| | | i..... | 3 46 30 | 6 | ..... | ..... | ..... | |
| | | i..... | 3 48 50 | 6 | ..... | ..... | ..... | |
| | | $eL_E$?.. | 3 54 42 | 12 | ..... | ..... | ..... | |
| | | $eL_N$?.. | 3 58 00 | 20 | ..... | ..... | ..... | |
| | | L..... | 4 05 00 | 22 | ..... | ..... | ..... | |
| | | L..... | 4 10 00 | 20 | ..... | ..... | ..... | |
| | | L..... | 4 24 00 | 20 | ..... | ..... | ..... | |
| | | L..... | 4 40 00 | 18 | ..... | ..... | ..... | |
| | | F..... | 5 00 00 | ..... | ..... | ..... | ..... | |

Canada. *Toronto. Dominion Meteorological Service.*

Lat., 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North; in the meridian.

Instrumental constant.. $T_0$ 18. Pillar deviation, 1 mm. swing of boom = 0.50″.

(Report for July, 1917, not received.)

Canada. *Victoria, B. C. Dominion Meteorological Service.*

Lat., 48° 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.

Instruments: Wiechert, vertical. Milne horizontal pendulum, North; in the meridian.

Instrumental constant.. $T_0$ 18. Pillar deviation: 1 mm. swing of boom = 0.54″.

(Report for July, 1917, not received.)

TABLE 3.—*Late seismological reports (instrumental).*

| Date. | Character. | Phase. | Time. | Period. T. | Amplitude. $A_E$ | Amplitude. $A_N$ | Distance. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| **New York.** *Ithaca. Cornell University.* **Heinrich Ries.** | | | | | | | | |
| Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters. | | | | | | | | |
| Instruments: Two Bosch-Omori 25 kg. horizontal pendulums. Mechanical registration. | | | | | | | | |
| Instrumental constants.. | | | | *V* | $T_0$ | $\epsilon$ | | |
| | | | | E 13 | 22 | 4:1 | | |
| | | | | N 14 | 25 | 4:1 | | |
| 1917. June 3 | ..... | $e_N$.... | *H. m. s.* 7 05 26 | *Sec.* 3 | *μ* ..... | *μ* ..... | *km.* ..... | |
| | | F..... | 7 10 30 | ..... | ..... | ..... | ..... | |
| 3 | ..... | $E_E$ ... | 19 48 01 | 5 | ..... | ..... | ..... | |
| | | $eL_E$... | 20 06 31 | 23 | ..... | ..... | ..... | |
| | | $F_E$... | 20 14 00 | ..... | ..... | ..... | ..... | |
| 4 | ..... | $eS_E$... | 1 46 06 | 6 | ..... | ..... | ..... | |
| | | $eS_N$... | 1 46 12 | 6 | ..... | ..... | ..... | |
| | | $eL_E$... | 1 57 47 | 20 | ..... | ..... | ..... | |
| | | $eL_N$... | 1 58 32 | 20 | ..... | ..... | ..... | |
| | | $F_N$.... | 2 22 00 | ..... | ..... | ..... | ..... | |
| | | $F_E$.... | 2 32 00 | ..... | ..... | ..... | ..... | |
| 7 | ..... | $L_E$.... | 3 19 51 | 16 | ..... | ..... | ..... | |
| | | $F_E$.... | 3 28 00 | ..... | ..... | ..... | ..... | |
| 8 | ..... | $e_N$.... | 0 57 45 | 3 | ..... | ..... | ..... | |
| | | $e_E$.... | 1 02 31 | 4 | ..... | ..... | ..... | |
| | | $M_E$.... | 1 08 46 | 14 | *1,000 | ..... | ..... | |
| | | $L_E$.... | 3 15 33 | 14 | ..... | ..... | ..... | |
| | | $F_N$.... | 3 24 00 | ..... | ..... | ..... | ..... | |
| | | $F_E$.... | 3 26 00 | ..... | ..... | ..... | ..... | |
| 9 | ..... | $eL_E$... | 18 00 34 | 22 | ..... | ..... | ..... | |
| | | $F_E$.... | 18 17 00 | ..... | ..... | ..... | ..... | |
| 10 | ..... | $e_E$.... | 4 39 26 | 4 | ..... | ..... | ..... | |
| | | $e_N$.... | 4 39 55 | 5 | ..... | ..... | ..... | |
| | | $eS_E$... | 4 45 12 | 10 | ..... | ..... | ..... | |
| | | $eL_E$... | 4 52 18 | 15 | ..... | ..... | ..... | |
| | | $eL_N$... | 4 52 19 | 16 | ..... | ..... | ..... | |
| | | $F_N$.... | 5 38 00 | ..... | ..... | ..... | ..... | |
| | | $F_E$.... | 5 44 30 | ..... | ..... | ..... | ..... | |
| 12 | ..... | $e_N$.... | 2 04 45 | 2 | ..... | ..... | ..... | |
| | | $e_E$.... | 2 04 46 | 2 | ..... | ..... | ..... | |
| | | $L_N$.... | 2 05 29 | 4 | ..... | ..... | ..... | |
| | | $F_E$.... | 2 06 00 | ..... | ..... | ..... | ..... | |
| | | $F_N$.... | 2 07 00 | ..... | ..... | ..... | ..... | |
| 13 | ..... | $e_N$.... | 7 07 01 | 16 | ..... | ..... | ..... | |
| | | $e_E$.... | 7 07 02 | 8 | ..... | ..... | ..... | |
| | | $L_N$.... | 7 31 50 | 40 | ..... | ..... | ..... | |
| | | $L_E$.... | 7 38 31 | 25 | ..... | ..... | ..... | |
| | | $F_E$.... | 9 06 00 | ..... | ..... | ..... | ..... | |
| | | $F_N$.... | 9 11 00 | ..... | ..... | ..... | ..... | |
| 16 | ..... | $eL_E$... | 16 08 32 | 15 | ..... | ..... | ..... | |
| | | F..... | 16 14 30 | ..... | ..... | ..... | ..... | |
| 24 | ..... | $e_E$.... | 20 08 00 | 5 | ..... | ..... | ..... | |
| | | $S_E$.... | 20 14 07 | 6 | ..... | ..... | ..... | |
| | | $i_N$.... | 20 14 54 | 6 | ..... | ..... | ..... | |
| | | $F_E$.... | 20 33 00 | ..... | ..... | ..... | ..... | |
| | | $F_N$.... | 21 03 00 | ..... | ..... | ..... | ..... | |
| 26 | ..... | $eP_E$... | 6 02 59 | 4 | ..... | ..... | ..... | Time clock not correct. |
| | | $eP_N$... | 6 03 46 | 3 | ..... | ..... | ..... | |
| | | $S_E$.... | 6 13 50 | 8 | *1,100 | ..... | ..... | |
| | | $i_E$.... | 6 16 59 | 10 | ..... | ..... | ..... | |
| | | $eL_E$... | 6 38 19 | 42 | ..... | ..... | ..... | |
| | | $M_N$.... | 6 46 39 | 20 | ..... | *3,500 | ..... | |
| | | $M_E$.... | 6 50 28 | 18 | *4,100 | ..... | ..... | |
| | | $F_E$.... | 10 15 00 | ..... | ..... | ..... | ..... | |
| 27 | ..... | $e_E$.... | 12 38 31 | 10 | ..... | ..... | ..... | |
| | | $L_E$.... | 12 42 28 | 32 | ..... | ..... | ..... | |
| | | F..... | 12 58 00 | ..... | ..... | ..... | ..... | |
| 28 | ..... | $eL_E$... | 14 50 42 | 18 | ..... | ..... | ..... | |
| | | F..... | 15 01 00 | ..... | ..... | ..... | ..... | |
| 29 | ..... | $e_N$.... | 16 22 51 | 6 | ..... | ..... | ..... | |
| | | $e_E$.... | 16 23 03 | 4 | ..... | ..... | ..... | |
| | | $F_N$.... | 16 45 00 | ..... | ..... | ..... | ..... | |
| | | $F_E$.... | 17 01 00 | ..... | ..... | ..... | ..... | |
| 30 | ..... | $eP_N$... | 17 56 22 | 4 | ..... | ..... | ..... | |
| | | $S_E$.... | 18 02 10 | 6 | ..... | ..... | ..... | |
| | | $S_N$.... | 18 02 11 | 5 | ..... | ..... | ..... | |
| | | $L_E$.... | 18 08 22 | 24 | ..... | ..... | ..... | |
| | | $L_N$.... | 18 12 41 | 17 | ..... | ..... | ..... | |
| | | $F_N$.... | 18 39 00 | ..... | ..... | ..... | ..... | |
| | | $F_E$.... | 18 42 00 | ..... | ..... | ..... | ..... | |

*Trace amplitude.

## SEISMOLOGICAL DISPATCHES.[1]

*Rome, July 9, 1917.*

Pope Benedict was awakened by an earth shock which shook the whole of Rome early Sunday morning. Many people dressed, others left their homes, fearing a second shock. The Pope inquired as to the extent of the earthquake and learned there was no damage or victims. The shock was specially felt at Avezzano, which was practically destroyed in the earthquake of January, 1915. (Assoc. Press.)

*Pago Pago, Tutuila, American Samoa* (July 10, 1917, mail correspondence).

The earthquake experienced here *June 25* was the severest shock in 50 years. After the tremor subsided a small tidal wave caused many people to take to the hillside for safety. The wave receded as suddenly as it came. The center of the disturbance was about 70 miles southwest of Samoa. Reports from Tongo stated that it was felt severely in that group, while at Keppet's Island the waters of the lagoon rose high on the island and left thousands of fish as they receded. (Assoc. Press.)

*Catania, Sicily, July 16, 1917.*

The most recent eruption of Mount Etna, although very brief, caused a panic among the population of the near-by districts in consequence of the enormous quantity of lava discharged, which surpassed previous records. (Assoc. Press.)

*Buenos Aires, July 27, 1917.*

An earthquake of great intensity in Chile was reported from Santiago in dispatches received to-day by La Nacion. The tremors have been felt in Santiago, Cordia, San Luis, Mendoza, Rosario, and Tucuman. In Buenos Aires slight tremors were noticeable. (Assoc. Press.)

*Washington, D. C., July 31, 1917.*

Official dispatches to the Chilean Embassy yesterday deny widely-published reports from Santiago, of an earthquake with great damage to Chilean cities. At the same time a quake was reported from Chile there actually was an earth disturbance in Argentina. (Assoc. Press.)

[1] Reported by the organization indicated and collected by the seismological station at Georgetown University, Washington, D. C.

# SECTION VI.—BIBLIOGRAPHY.

## RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

**Adams, John.**
Quantitative study of climatic factors in relation to plant life. Ottawa. 1916. cover-title. tables. 25 cm. (Reprinted from the Transactions of the Royal society of Canada, ser. 3, v. 10, p. 105–123.)

**Bauer, Louis Agricola,** *and others.*
Ocean magnetic observations 1905–1916 and reports on special researches. Washington. 1917. vii, 447 p. front. plates. tables. charts. maps (partly fold.) figures. 30½ cm. At head of title: Researches of the Department of terrestrial magnetism [Carnegie institution] volume 3. [Publication no. 175.] [Results of atmospheric-electric observations made aboard the Galilee (1907–1908), and the Carnegie (1909–1916), by L. A Bauer and W. F. G. Swann, p. 361–422.]

**Bouches-du-Rhône. Commission de météorologie.**
Bulletin annuel. Année 1915=34e année. Marseille. 1916. xii, 68, xxviii p. tables. map. charts. (partly fold.) 28½ cm.

**Cienfuegos. Colegio "Ntra. Sra. de Montserrat." Observatorio.**
Anales . . . No. 6. Observaciones meteorológicas de 1916. Habana. 1917. [4], 7, [77] p. tables. 34 cm.

**Dickerson, Roy E.**
Climate and its influence upon the Oligocene faunas of the Pacific coast, with descriptions of some new species from the *Molopophorus lincolnensis* zone. Climatic zones of Martinez Eocene time. San Francisco. 1917. cover-title. plates. map. 25½ cm. (Proceedings of the California academy of sciences, 4th ser. v. 7, nos. 6–7, p. 157–196.)

**Galli, Ignazio.**
Supplemento alla storia, ai caratteri e agli effetti del fulmine globulare. Memoria sesta. Roma. 1916. 70 p. 29cm. (Estratto dalle Memorie delle Pontificia accademia romana dei Nuovi Lincei, ser. 2, v. 2.)

**Great Britain. Meteorological office.**
Réseau mondial, 1912. Table representing the meteorology of the globe for . . . 1912 by means of stations selected at the rate of two for each ten-degree square. London. [1917.] 112 p. tables. 32cm. [Appears monthly with annual summary.]

**Harvard college. Astronomical observatory.**
Annals. Volume 83, Part 1. Observations and investigations made at the Blue Hill meteorological observatory in the year 1916. Cambridge, Mass. 1917. [3 l.] 59 p. tables. charts. 30cm.

**Hegner, Caspar Frank.**
Lightning; some of its effects. plate. 25cm. (Reprinted from Annals of surgery for April, 1917, p. 401–409.)

**Meyer, Adolph F[rederick].**
Elements of hydrology. New York. 1917. xii, 487 p. illus. tables. maps (partly fold). charts (partly fold.) 23½cm.

**Minas Geraes. Serviço de meteorologia.**
Dados meteorologicos de 1910 a 1914. Bello Horizonte. 1916. [2 l.] 5–106 p. [1] tables. charts. 32½ x 34½ cm.

**Norway. Norske meteorologiske institut.**
Jahrbuch für 1916. Kristiania. 1917. xii, 167 p. tables. chart. 33½cm.
Nedbøriagttagelser i Norge. Aargang 21, 1916. xi [l.] [3]–45 p. figures. tables. 2 fold. charts. 37½cm.

**Palmer, George T[homas].**
Are schoolrooms drier than deserts? illus. tables. 23cm. (Reprinted from Journal of the American society of heating & ventilating engineers, July, 1917, p. 525–539.)

**Philip, George, & son, limited.**
Comparative wall atlas of the British Isles; ed. by J. F. Unstead and E. G. R. Taylor. 3. Temperature. 4. Annual rainfall, isobars & winds. 2 col. maps. 86½ x 111 cm. At bottom of map: The London geographical institute.

**Sleight, R[euben] B.**
Evaporation from the surfaces of water and river-bed materials. Washington. 1917. cover-title. plates 33–38. tables. 13 figs. 26cm. (Reprinted from Journal of agricultural research, v. 10, no. 5.) Literature cited, p. 259–261.

**Straits Settlements [Principal civil medical officer].**
Meteorological returns for the year 1916. Singapore. 1917. 9 [60] p. [12 l.] tables. 34cm.

**Switzerland. Schweizerische meteorologische Zentral-Anstalt.**
Annalen, 1915. Der Schweizerischen meteorologischen Beobachtungen, Zweiundfünfzigster Jahrgang. Zürich. [1916] viii, [273] p. tables. charts (partly fold., partly col.) fold. map. 31cm. Various pagings.

**Taylor, Griffith.**
Syllabus of lectures on meteorology for aviators. Melbourne [1915] 16 p. 21½cm. At head of title: Commonwealth military forces. Central flying school, Point Cooke, Victoria.

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## RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following titles have been selected from the contents of the periodicals and serials recently received in the library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of the meteorological contents of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

*Agricultural gazette of Canada. Ottawa. v. 1. August, 1917.*
**Cameron, Alfred E.** The relation of soil insects to climatic conditions. p. 663–669.

*Engineering news-record. New York. v. 79. 1917.*
**Horton, Robert E.** Rational study of rainfall data makes possible better estimates of water yield. p. 211–213. (Aug. 2.)
**Horton, Robert E.** Drainage-basin and crop studies aid water-supply estimates. p. 357–360. (Aug. 23.)
**Gilkey, H. J.** Freezing ground acts likes hydraulic jack. p. 360–361. (Aug. 23.)

*Franklin institute. Journal. Philadelphia. v. 184. August, 1917.*
**Humphreys, W[illiam] J[ackson].** Physics of the air. p. 137–178.

*Geographical review. New York. v. 4. August, 1917.*
**Carey, J. P.** The central Illinois tornado of May 26, 1917. p. 122–130.
**Ward, Robert DeC.** Rainfall types of the United States. p. 131–144.

*London, Edinburgh and Dublin philosophical magazine. London. v. 34. August, 1917.*
**Jeffreys, Harold.** On periodic convection currents in the atmosphere. p. 112–128.

*Nature. London. v. 99. 1917.*
**Chree, C[harles].** Photographs of aurora. p. 405–406. (July 19.)
**Dines, W[illiam] H[enry].** Meteorology and aviation. p. 424–426. (July 26.)
**Mill, Hugh Robert.** Forests and rainfall. p. 455–446. (Aug. 2.) [Review of memoir by M. Hill.]
**Hawke, E. L.** Rainfall and gunfire. p. 467–468. (Aug. 9.) [Summary of paper by Angot.]

*Royal meteorological society. Quarterly journal. London. v. 43. July, 1917.*
**Taylor, G. I.** The formation of fog and mist. p. 241–268.
**Bilham, E. G.** The diurnal variation of atmospheric pressure at Benson, Oxon, during the year 1915. p. 269–281.
**Whipple, F. J. W.** The significance of the harmonic analysis of diurnal variation of pressure. p. 282–283. [Discussion of E. G. Bilham's paper.]
**Clark, J. Edmund, & Adames, Henry B.** Report on the phenological observations in the British islands, from December, 1915, to November, 1916. p. 285–316.
**Ward, Robert DeC.** The tornadoes of the United States as climatic phenomena. p. 317–329.
**Dines, W[illiam] H[enry].** Correlation in seasonal variations of weather. p. 333–335.
**N., W. C.** Mr. William Ellis, F. R. S. p. 335-337. [Obituary.]
**G., W. V.** Mr. Baldwin Latham, 1836–1917. p. 337–338. [Obituary.]

*Royal society of Edinburgh. Proceedings. Edinburgh. v. 37. pt. 3. 1916–1917.*

**Becker, L.** The arithmetical mean and the "middle" value of certain meteorological observations. p. 210–214.

**Aitken, John.** On some nuclei of cloudy condensation. p. 215–245.

*Science. New York. v. 46. 1917.* (Aug. 3.)

**William Bullock Clarke**(!) p. 104–106. [Obituary—Prof. Clark was director of the Maryland Weather Service; see this REVIEW, p. 367.]

**Keyes, Charles.** Climatic index of Bonneville lake beds. p. 139–140. (Aug. 10.)

*Scientific American supplement. New York. v. 83. 1917.*

**McAdie, Alexander.** Aviation and aerography. p. 341–342. (June 2.)

**Lawrence, W. H.** The wireless storm detector. Its influence upon the operation of lighting central stations. p. 78–79. (Aug. 4.)

*Scientific American supplement. New York. v. 84. 1917.*

**Palmer, Andrew H.** The effect of the weather on forest fires. p. 88–89. (Aug. 11.)

**Bliss, Geo[rge] S.** The weather business. A history of weather records, and the work of the U. S. Weather Bureau. p. 110–111. (Aug. 18.) [Report from Journal of the Engineers' Club of Philadelphia.]

*Scientific monthly. New York. v. 5. September, 1917.*

**Palmer, Andrew H.** Climatic influences on American architecture. p. 270–283.

*Scottish meteorological society. Journal. Edinburgh. ser. 3. v. 17. no. 33.*

**Shaw, Napier.** The distribution of cloud and rain with reference to the center of a cyclonic depression. p. 90–92.

**W[att], A[ndrew].** Audibility and meteorological conditions. p. 94–97.

*Imperial earthquake investigation committee. Bulletin. Tokyo. v. 7. no. 2. 1917.*

**Omori, F.** The eruptions and earthquakes of the Asama-Yama. No. 5. p. i–iii, 217–326.

*Annales de géographie. Paris. 26 année. 15 juillet 1917.*

**Angot, Alfred.** Régime pluviométrique de la France. p. 255–272.

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## SECTION VII.—WEATHER AND DATA FOR THE MONTH.

### THE WEATHER OF JULY, 1917.

P. C. DAY, Climatologist and Chief of Division.

[Dated: Washington, Aug. 31, 1917.]

#### PRESSURE AND WINDS.

The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing direction of the winds are graphically shown on Chart VII (XLV–74) while the average values for July, 1917, at the several stations, with departures from the normal, are shown on Tables I and III.

At the beginning of the month low barometric pressure obtained in the region of the Great Lakes and over the eastern Canadian Provinces, but a high-pressure area of considerable magnitude, for the season of the year, occupied the far Northwest and moved thence during the following few days slowly eastward over the central and northern districts. During much of the time from the 6th to the middle of the third decade stagnant pressure conditions obtained with relatively low values persisting in most sections of the country, specially east of the Mississippi River, and with a high-pressure area overlying the ocean to the east. There was no well-defined storm movement during the month, although at the close a rather marked low-pressure area had advanced from the far Northwest to the upper Mississippi Valley.

For the month as a whole the pressure averaged below the normal generally, except in the Atlantic and Gulf Coast States, where it was mostly normal or slightly above, also the case in some sections of the Rocky Mountain and Plateau districts of the West. The negative departures were rather marked in the northern border States from the Great Lakes westward to the Rocky Mountains, in the central Mississippi and lower Missouri Valleys.

The distribution of atmospheric pressure during the month was such as to favor frequent southerly winds, and these prevailed in all sections of the country except in some far western districts and locally elsewhere.

#### TEMPERATURE.

During the first decade of July, 1917, temperature was below the monthly average generally east of the Mississippi River and above that value in the West. The weather was specially cool in the region of the Great Lakes and warm in the Plateau districts of the West. West of the Rocky Mountains, hot weather continued throughout the second decade, the week ending July 17 being specially warm in Nevada and eastern Oregon, where the temperature for the week averaged 9 to 12 degrees above normal. In the Lakes Region the unseasonably cool weather, which had persisted for about two months, continued until near the end of the second decade, when warmer weather set in. During the latter part of the third decade the hot period that had persisted for more than a month in the far West, came to an end. About the same time much warmer weather set in over most eastern districts, the afternoon temperatures rising to 100°, or higher, in the middle and lower Missouri and upper Mississippi Valleys, and reaching nearly 100° at many points in the Middle Atlantic and Northeastern States.

For July, as a whole, the temperature averaged above the July normal in all districts, except in most of Michigan and the lower Lakes Region, the Ohio and middle Mississippi Valleys, and the Middle Atlantic States, where it was deficient. The negative departures were not marked, however, being generally less than 3 degrees. The greatest positive departures occurred in portions of Nevada and California, where the month was 6 degrees or more warmer than the July average.

The cool weather during much of the month in eastern districts was due to the prevalence of cloudy weather, which prevented the day temperatures from going as high as they usually do in July. On the other hand there was an unusually large amount of sunshine in much of the Plains Region, in the central, and the northern Plateau district of the West; consequently the day temperatures in those sections were persistently higher than those usually experienced there in July.

#### PRECIPITATION.

During the first two decades of July, 1917, there was abundant rainfall over nearly all the great agricultural districts from the Plains States eastward. In fact, rain persisted to such an extent as greatly to interfere with farming operations, especially in the more eastern districts; there was urgent need of dry weather to permit the completion of harvesting, the gathering of small grains, haying, and much needed cultivation of all growing crops.

In the western districts, however—especially in the Plains States, and from the Dakotas westward to the Pacific—the rainfall was exceedingly light. In Kansas this July and the two-months period June–July, were the driest ever recorded in the State. The drought conditions were further intensified in many sections of the Plains Region by the frequent occurrence of hot, dry winds, which greatly increased evaporation from the soil. In western South Dakota, over much of North Dakota, Montana, and the far Northwest, where considerable rainfall usually occurs during midsummer, the July precipitation was exceedingly small, and severe drought existed in many portions of these States at the end of the month. In much of Texas and thence westward to and including the greater part of New Mexico the month was without beneficial rain; in fact, over portions of this area the precipitation has been deficient for many months, the soil is unusually dry, the cattle ranges are poor, and water scarce. In Arizona, portions of Utah and Colorado, the usual summer rains were very generally reported.

For July as a whole the precipitation was far in excess of the normal fall over the Atlantic coast districts from southern New England to northern Florida, over portions of the Gulf States, the Mississippi and Ohio Valleys. It was approximately normal over most other districts east of the Plains States, over Arizona and portions of adjoining States. Over much of the Great Plains region and thence northwestward the precipitation was nearly everywhere below the normal and in some districts the amounts for the month were the least of record.

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### RELATIVE HUMIDITY.

Over the districts from the Mississippi River eastward, due to much cloudy weather and frequent showers, the relative humidity was nearly everywhere above the normal. West of the Mississippi, except over Arizona and portions of some adjoining States, the relative humidity was very generally far below the average. This was particularly true for the Great Plains, Montana, and Wyoming, where the deficiencies frequently amounted to 10 to 20 per cent. This dry condition of the atmosphere, together with an unusual amount of wind movement in portions of the central Plains States, favored rapid evaporation of soil moisture and growing vegetation suffered greatly thereby.

### GENERAL SUMMARY.

On the whole during July, 1917, the weather over the central and eastern districts was—nearly everywhere—favorable for plant growth, due to a plentiful supply of soil moisture and to moderate temperature conditions. In portions of the corn belt, particularly in Iowa and thence eastward the early part of the month favored rapid crop growth, but corn continued late on account of persistent cool weather. The hot wave in the latter part of the month, especially the warm nights, greatly favored both growth and development and at the end of the month the crop was reported in splendid condition and nearly up to the stage of growth normal for the end of July.

In portions of the western corn belt, especially in Kansas and parts of surrounding States, the lack of rain and the continued hot, drying winds greatly injured corn and other growing crops. Farther north, in the spring-wheat region, lack of rain and intense heat forced the growing wheat too rapidly and seriously injured the quality of the grain, especially over the more western districts. The continued showery weather over eastern districts materially interfered with the gathering and threshing of the grain crop, but in the more western States this work made rapid progress.

In the Cotton States the weather, on the whole, was favorable and the general condition of the cotton crop remained about as reported at the end of June.

The severe heat of the last few days of the month caused much suffering and many deaths in the larger cities of the northeastern States, the temperatures during this period being as high as, or higher than, previously recorded at a number of points. This was particularly true of the night temperatures, which were in many cases likewise the highest ever observed in July.

### SEVERE LOCAL STORMS.

The following notes of severe storms during July, 1917, have been extracted from reports by officials of the Weather Bureau:

*Illinois.*—A damaging wind and hail storm of tornadic character occurred on July 13 in Rock Island County. The storm covered an area of about 2½ miles wide and 6 miles long. It seriously injured all growing crops, some farms suffering total loss. The estimated loss was about $75,000 in all.

On the same afternoon another storm of like nature destroyed residences and crops in Champaign and Vermilion Counties, with several persons injured and one reported fatality. Nearly every residence in Fairmont, Champaign County, was damaged; trees were laid flat, and miles of telephone poles were stripped.

*Indiana.*—A number of local storms occurred, causing some damage by wind, hail, or heavy rain, and at least one of these—in the northern portion of Brown County—was of a tornadic type.

*New England.*—During a storm on July 21 at North Bridgton, Me., 3.11 inches of rain fell between 3 and 6 p. m.; at Holyoke, Mass., 4.67 inches fell in 2½ hours. Severe hail storms and high winds occurred in portions of the Connecticut Valley, seriously damaging growing crops.

*New York.*—Thunderstorms were unusually frequent in all sections of the State and in some cases they were severe. Several deaths were reported from their destructive effects, while crops suffered from the sudden heavy falls of rain and severe gusty winds.

*Wisconsin.*—Unusually heavy rainfall occurred in Vernon County, most of it in connection with severe thunderstorms on July 21 and 22. Severe freshets in the rivers and creeks were the result, with damages to property estimated at $150,000.

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*Average accumulated departures for July, 1917.*

| Districts. | Temperature. | | | Precipitation. | | | Cloudiness. | | Relative humidity. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | General mean for the current month. | Departure for the current month. | Accumulated departure since Jan. 1. | General mean for the current month. | Departure for the current month. | Accumulated departure since Jan. 1. | General mean for the current month. | Departure from the normal. | General mean for the current month. | Departure from the normal. |
| | °F. | °F. | °F. | In. | In. | In. | 0–10 | | P. ct. | |
| New England | 69.7 | +0.8 | −11.5 | 2.35 | −1.20 | −0.50 | 5.8 | +0.7 | 82 | +2 |
| Middle Atlantic | 74.6 | −0.1 | −4.8 | 5.03 | +0.70 | −1.10 | 6.3 | +1.4 | 79 | +6 |
| South Atlantic | 78.9 | −0.2 | +5.2 | 7.31 | +1.30 | −3.30 | 5.6 | +0.8 | 82 | +3 |
| Florida Peninsula | 82.1 | +0.2 | +3.2 | 3.50 | −2.90 | −10.40 | 4.1 | −0.9 | 75 | −3 |
| East Gulf | 80.2 | −0.1 | +4.0 | 5.09 | +0.40 | −1.70 | 5.5 | +0.1 | 78 | 0 |
| West Gulf | 82.7 | +0.8 | +2.7 | 3.73 | +0.60 | −7.30 | 3.6 | −0.7 | 69 | −6 |
| Ohio Valley and Tennessee | 75.1 | −1.4 | −10.6 | 4.28 | +0.30 | +2.70 | 5.4 | +0.6 | 75 | +4 |
| Lower Lakes | 71.4 | −0.3 | −17.4 | 2.63 | −0.80 | +0.50 | 4.7 | +0.1 | 74 | +4 |
| Upper Lakes | 67.8 | 0.0 | −21.3 | 2.91 | −0.20 | −1.20 | 4.8 | +0.1 | 78 | +5 |
| North Dakota | 71.9 | +2.8 | −12.3 | 1.07 | −1.80 | −6.50 | 3.2 | −1.0 | 61 | −5 |
| Upper Mississippi Valley | 75.2 | −0.2 | −16.1 | 3.40 | −0.20 | −0.10 | 4.2 | −0.2 | 70 | +1 |
| Missouri Valley | 77.7 | +2.0 | −5.8 | 1.85 | −2.00 | −2.90 | 2.7 | −1.5 | 60 | −5 |
| Northern slope | 71.7 | +3.6 | −16.9 | 0.62 | −0.90 | −0.80 | 3.0 | −0.7 | 48 | −8 |
| Middle slope | 79.3 | +2.6 | −3.5 | 1.56 | −1.40 | −5.10 | 3.5 | −0.6 | 51 | −10 |
| Southern slope | 82.7 | +2.2 | +2.9 | 1.00 | −1.80 | −4.70 | 2.9 | −1.3 | 47 | −13 |
| Southern Plateau | 80.8 | +1.8 | −9.1 | 1.07 | −0.20 | −1.10 | 4.3 | +0.9 | 43 | +3 |
| Middle Plateau | 76.6 | +3.8 | −28.7 | 0.40 | −0.10 | −1.00 | 2.9 | −0.1 | 36 | 0 |
| Northern Plateau | 74.7 | +3.8 | −19.9 | 0.40 | −0.40 | −1.00 | 2.4 | −0.4 | 38 | −5 |
| North Pacific | 64.1 | +1.2 | −12.1 | 0.20 | −0.50 | −5.00 | 3.2 | −1.4 | 68 | −7 |
| Middle Pacific | 67.8 | +2.3 | −7.9 | 0.00 | 0.00 | −6.20 | 2.8 | −0.1 | 55 | −6 |
| South Pacific | 73.4 | +3.5 | −1.0 | 0.00 | 0.00 | −2.30 | 2.9 | +0.2 | 64 | 0 |

### WEATHER CONDITIONS OVER THE NORTH ATLANTIC OCEAN DURING JULY, 1916.

The data for the North Atlantic Ocean presented are for July, 1916, and comparison and study of the same should be in connection with those appearing in the REVIEW for that month. Chart IX (XLV—75) shows for July, 1916, the average pressures, temperatures, and prevailing directions of the wind at 7 a. m., 75th meridian time (Greenwich mean noon), together with notes on the locations and courses of the more severe storms of the month.

### PRESSURE.

The distribution of the average monthly pressures as shown on Chart IX differed but little from the normal in the middle and higher latitudes, although the West Indies hurricanes that prevailed during the month were respon-

sible for slightly lower pressures than usual in the Caribbean Sea and Gulf of Mexico. The North Atlantic HIGH was practically normal in intensity, position, and extent, while the isobar of 29.9 inches was slightly north of its usual location and marked the southern limits of the Icelandic LOW. The pressure changes from day to day were pronounced in the upper latitudes and over a large area in midocean, while in the vicinity of the Azores and in equatorial regions the range was comparatively small. The average pressure for each of the three decades differed considerably in some localities, and especially north of the 60th parallel. The following table gives the mean pressure for the three decades of the month for different 5-degree squares, as well as the highest and lowest reported individual readings during the month within the respective squares.

*Pressures over the North Atlantic during July, 1916, by 5-degree squares.*

| Position of 5-degree square. | | Decade means. | | | Extremes. | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Highest. | | Lowest. | |
| Latitude. | Longitude. | I | II | III | Pressure. | Date. | Pressure. | Date. |
| ° | ° | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *July.* | *Inches.* | *July.* |
| 60-65 N | 20-25 W | 30.00 | 29.75 | 29.77 | 30.11 | 3 | 29.58 | 15,25 |
| 60-65 N | 10-15 W | 29.92 | 29.84 | 29.93 | 30.20 | 23 | 29.68 | 10 |
| 60-65 N | 0- 5 E | 29.79 | 29.86 | 30.09 | 30.21 | 22,24 | 29.66 | 9 |
| 55-60 N | 35-40 W | 30.05 | 29.77 | 29.91 | 30.22 | 9 | 29.48 | 15 |
| 50-55 N | 0- 5 E | 29.82 | 30.01 | 30.19 | 30.33 | 29 | 29.60 | 8 |
| 45-50 N | 60-65 W | 29.88 | 29.97 | 30.00 | 30.32 | 15 | 29.60 | 1,21 |
| 45-50 N | 40-45 W | 30.03 | 30.04 | 30.09 | 30.38 | 17 | 29.70 | 5 |
| 45-50 N | 5-10 W | 29.94 | 30.21 | 30.25 | 30.42 | 29 | 29.84 | 8 |
| 40-45 N | 15-20 W | 30.10 | 30.32 | 30.25 | 30.42 | 28,29 | 29.90 | 7 |
| 35-40 N | 40-45 W | 30.29 | 30.32 | 30.31 | 30.43 | 8,11 | 30.12 | 1 |
| 30-35 N | 55-60 W | 30.17 | 30.23 | 30.28 | 30.40 | 24 | 30.08 | 1,6 |
| 30-35 N | 25-30 W | 30.23 | 30.31 | 30.21 | 30.41 | 14 | 30.09 | 25 |
| 25-30 N | 80-85 W | 29.96 | 29.99 | 30.02 | 30.09 | 25 | 29.82 | 4 |
| 20-25 N | 70-75 W | 30.01 | 29.95 | 30.02 | 30.09 | 26 | 29.80 | 16,17 |
| 15-20 N | 35-40 W | 30.09 | 30.02 | 30.03 | 30.20 | 2,3 | 29.98 | 7,13,18 |

The mean and extreme pressures presented in the above table are based on the daily interpolated values for each square as given on the MS daily synoptic charts of the North Atlantic compiled by the Marine Section of the Weather Bureau.

## GALES.

Usually July has fewer gales than any other month except June; and in July, 1916, the number of gales was below even the average for the month over the greater part of the Atlantic lying north of the 40th parallel. A succession of West Indies hurricanes was responsible for the unusually large number reported from the Gulf of Mexico and the Caribbean Sea. This is specially noticeable in the 5-degree square between latitudes 25°–30°, longitudes 65°–70°, where gales were reported on 4 days, a percentage of 13, while the normal percentage for this square is less than 1. In an article in the MONTHLY WEATHER REVIEW for December, 1916, 44: 686–688 (Hurricanes of 1916 and Notes on Hurricanes of 1912–1915, by R. H. Weightman), three West Indies hurricanes that appeared in July, 1916, were described and plotted. These are shown as tracks *I*, *II*, and *III*, respectively, on Chart IX (XLV–75), *III* being extended from July 20 to July 25.

On July 1 several slight depressions north of the 40th parallel were attended by light to moderate winds, and a LOW of slight intensity (*I* on Chart IX) was near latitude 16° N., longitude 84° W. By the 2d *I* had moved a short distance toward the north, with its center about 50 miles west of Swan Island, the condition of wind and weather having changed but little since the previous day. The LOW continued in its slow northerly movement, without increase of energy until the 4th, when it was near latitude 24° N., longitude 87° W. On that date the barometer had fallen to 29.45 inches, and vessels near the center reported winds of 60 to 65 miles an hour. On the 5th the center was in the vicinity of Pensacola, Fla., where the barometer reading was 29.56 inches. The disturbance then followed a very irregular path, as shown on Chart IX, and on the 10th was near Cairo, Ill.

From July 6 to 11 the atmospheric conditions over the entire ocean were sluggish, with weak gradients and light winds, with fog prevailing along the New England coast during the greater part of the period. On the 12th a LOW (*II* on Chart IX) was central near latitude 26° N., longitude 75° W., one vessel reporting a southwesterly gale of about 50 miles an hour, with a barometer reading of 29.79 inches. On the 13th this center was near Nassau, but no winds of gale force were reported by any vessel in the vicinity. It continued on its northwesterly course, and on the 14th was central near Charleston, S. C., while on the following day it was in the vicinity of Charlotte, N. C.

On the 12th a LOW of light intensity was near Barbadoes, and moving rapidly toward the northwest, reaching the island of Porto Rico on the 13th. It was too far south to plot on Chart IX on these dates, but on the 14th it appears as Low *III*, the center being near latitide 21°, longitude 66°; easterly and southeasterly gales of 40 to 50 miles an hour were encountered in the northerly quadrants. The rate of translation was slow during the next three days, for on the 17th the disturbance was near latitude 24°, longitude 71°, where winds of gale to hurricane force were reported during this period, while on the 16th a vessel near latitude 22°, longitude 69°, recorded a northwesterly wind of 90 miles or over, with a barometric reading of 29.33 inches.

The path of *III* curved slightly toward the north, and on the 19th the center was about 100 miles south of Hatteras. Winds of gale force still prevailed, the velocity ranging from 40 to 65 miles an hour over a limited area. On the 20th the center of the disturbance was about 3 degrees east of Norfolk, Va., gales still raging along the coast between the 35th and 38th parallels. It then curved toward the northeast, following the coast line, and on the 21st was central near Nantucket, the force of the wind having moderated considerably since the previous day. On the 22d the disturbance covered the greater part of the Gulf of St. Lawrence, moderate winds and fog prevailing, and then moved rapidly toward the northeast, the center on the 23d being near latitude 52°, longitude 35°, accompanied by moderate southerly gales. It then curved toward the north, and on the 24th was in the vicinity of latitude 53°, longitude 27°, but the area had increased so in extent and so few observations were received from the northern quadrants, it was impossible to locate the center accurately. On the 25th the disturbance was off the south coast of Iceland, the barometer reading at Reykjavik being 29.50 inches.

As stated previously there were few cyclonic disturbances of any force in the northern division of the Atlantic and the winds were for the most part from light to moderate. From the 14th to the 17th, however, there was an area of low pressure of light intensity, that covered an extensive territory in northern waters, and a few reports were received from vessels in widely scattered localities that experienced gales of 40 to 50 miles an hour.

### TEMPERATURE.

The average monthly temperature of the air over the ocean, was as a whole, considerably above the normal north of latitude 40, the positive departures ranging from 1 to 5 degrees. Between the 30th and 40th parallels, west of the 30th meridian, it was, for the most part, slightly cooler than usual; the same conditions held true in the waters adjacent to the American coast, while in the Gulf of Mexico the temperature was practically normal. The departures at a number of Canadian and U. S. Weather Bureau stations on the Atlantic and Gulf coasts, were unusually variable, as shown in the following table:

| | °F. | | °F. |
|---|---|---|---|
| St. Johns, N. F. | +1.8 | Norfolk, Va. | −1.0 |
| Sydney, C. B. I. | +1.2 | Hatteras, N. C. | −0.9 |
| Halifax, N. S. | +1.7 | Charleston, S. C. | −2.2 |
| Eastport, Me. | −1.0 | Key West, Fla. | −1.4 |
| Portland, Me. | −0.1 | Tampa, Fla. | +1.6 |
| Boston, Mass. | +1.3 | Mobile, Ala. | −0.5 |
| Nantucket, Mass. | −2.1 | New Orleans, La. | +1.0 |
| Block Island, R. I. | −1.0 | Galveston, Tex. | −0.2 |
| New York, N. Y. | +0.3 | Corpus Christi, Tex. | 0.0 |

The lowest temperature reported during the month was 48° F., and occurred in the waters adjacent to the east coast of Labrador, between the 50th and 55th parallels; the highest temperature, 58°, was for the same square and was recorded on a number of different days.

### FOG.

Off the Banks of Newfoundland, where the number of days on which fog occurs is usually the greatest, it was reported during July, 1916, on 14 days, which is slightly less than usual. On the other hand, over the Nantucket Shoals it was encountered on 20 days, a percentage of 65, while the normal for that region is between 40 and 50 per cent. In mid-ocean and over the eastern portion of the steamer lanes, the amount varied but little from the normal, being slightly above in some localities and below in others.

*Winds of 50 mis./ hr. (22.4 m./ sec.), or over, during July, 1917.*

| Station. | Date. | Velocity. | Direction. | Station. | Date. | Velocity. | Direction. |
|---|---|---|---|---|---|---|---|
| | | *Mis./hr.* | | | | *Mis./hr.* | |
| Buffalo, N. Y. | 9 | 72 | nw. | Mt. Tamalpais, Cal. | 26 | 54 | w. |
| Columbus, Ohio | 1 | 58 | nw. | Do. | 27 | 52 | nw. |
| Duluth, Minn. | 29 | 54 | sw. | New York, N. Y. | 2 | 50 | sw. |
| Jacksonville, Fla. | 12 | 50 | sw. | Norfolk, Va. | 10 | 66 | nw. |
| Do. | 14 | 60 | sw. | Do. | 12 | 55 | w. |
| Do. | 28 | 54 | s. | Do. | 27 | 54 | w. |
| Do. | 30 | 52 | ne. | Pierre, S. Dak. | 30 | 70 | w. |
| Memphis, Tenn. | 19 | 64 | nw. | Point Reyes Light, Cal. | 27 | 50 | nw. |
| Mobile, Ala. | 6 | 50 | n. | Sandy Hook, N. J | 2 | 71 | s. |
| Mt. Tamalpais, Cal. | 19 | 54 | nw. | Do. | 14 | 62 | nw. |
| Do. | 20 | 64 | nw. | San Juan, P. R. | 12 | 50 | e. |
| Do. | 22 | 56 | nw. | Trenton, N. J. | 2 | 52 | w. |
| Do. | 23 | 52 | w. | | | | |

## CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

*Condensed climatological summary of temperature and precipitation by section, July, 1917.*

| Section. | Temperature. | | | | | | | | Precipitation. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Section average. | Departure from the normal. | Monthly extremes. | | | | | | Section average. | Departure from the normal. | Greatest monthly. | | Least monthly. | |
| | | | Station. | Highest. | Date. | Station. | Lowest. | Date. | | | Station. | Amount. | Station. | Amount. |
| | °F. | °F. | | °F. | | | °F. | | In. | In. | | In. | | In. |
| Alabama | 79.6 | −0.4 | 2 stations | 101 | 31 | Hamilton | 54 | 11 | 6.01 | +0.90 | Mobile | 10.54 | Flomaton | 1.81 |
| Arizona | 80.6 | +1.4 | Mohawk | 117 | 14 | 2 stations | 39 | 6† | 3.62 | +1.13 | Honeymoon | 11.87 | Tuba City | 0.47 |
| Arkansas | 79.6 | −0.3 | 3 stations | 106 | 1† | Dutton | 50 | 4 | 5.10 | +1.18 | Bergman | 10.60 | 2 stations | 2.00 |
| California | 75.8 | +1.8 | Delta | 119 | 18 | Cahuilla | 23 | 6 | 0.08 | +0.04 | Sierraville | 2.60 | 103 stations | 0.00 |
| Colorado | 67.7 | +1.9 | Holyoke | 107 | 27 | Fraser | 26 | 2 | 1.67 | −0.70 | Silver Lake | 5.18 | Dolores | 0.00 |
| Florida | 81.2 | −0.2 | 5 stations | 99 | 13† | Davie | 62 | 28 | 6.62 | −0.34 | De Funiak Springs | 13.68 | Long Key | 0.63 |
| Georgia | 80.0 | +0.2 | Statesboro | 102 | 9 | Blue Ridge | 53 | 11 | 5.05 | −0.68 | Eastman | 11.40 | Atlanta | 1.98 |
| Hawaii [June report] | 73.2 | +0.4 | Mahukona, Hawaii | 96 | 9 | Volcano Observatory | 49 | 5 | 3.49 | −1.21 | Hakalau (Mauka) | 14.25 | 5 stations | 0.00 |
| Idaho | 69.0 | +2.8 | Weiser | 111 | 8 | New Meadows | 20 | 30 | 0.27 | −0.46 | Malad | 1.65 | 20 stations | 0.00 |
| Illinois | 75.1 | −0.8 | Ottawa | 103 | 30 | Minonk | 44 | 3 | 2.86 | −0.75 | McLeansboro | 8.42 | Newton | 0.24 |
| Indiana | 73.7 | −1.6 | 2 stations | 100 | 30† | 3 stations | 42 | 3† | 3.26 | −0.28 | Salamonia | 7.23 | Frankfort | 1.06 |
| Iowa | 74.3 | +0.2 | Clarinda | 106 | 30 | Rock Rapids | 38 | 3 | 2.27 | −1.69 | Nora Springs | 6.06 | Northboro | 0.23 |
| Kansas | 80.8 | +3.0 | Wellington | 112 | 13 | Blakeman | 44 | 16 | 1.50 | −2.30 | Arkansas City | 4.23 | 2 stations | T. |
| Kentucky | 75.3 | −1.5 | Loretto | 100 | 31 | 3 stations | 50 | 4† | 4.38 | +0.03 | Frankfort | 8.16 | Louisville | 1.86 |
| Louisiana | 82.5 | +0.8 | 4 stations | 107 | 7† | Jeanerette | 60 | 20 | 5.58 | −0.54 | Franklin | 9.93 | Cinclare | 1.41 |
| Maryland-Delaware | 74.9 | −0.6 | Cumberland, Md | 102 | 31 | Oakland, Md | 45 | 4† | 6.36 | +2.11 | Ferry Landing, Md | 14.76 | Fallston, Md | 3.22 |
| Michigan | 68.3 | −0.6 | Marquette | 105 | 29 | Humboldt | 32 | 4 | 2.62 | −0.25 | Plainwell | 7.72 | St. James | 0.67 |
| Minnesota | 70.8 | +1.2 | Beardsley | 114 | 29 | Brainerd | 33 | 4 | 3.33 | −0.22 | Mora | 6.66 | Moorhead | 0.81 |
| Mississippi | 81.0 | +1.5 | Brookhaven | 104 | 11 | Duck Hill | 57 | 13 | 4.89 | −0.59 | Fruitland Park | 11.52 | Tupelo | 1.90 |
| Missouri | 77.5 | +0.2 | Mexico | 107 | 31 | Steffenville | 42 | 4 | 2.96 | −1.22 | Dean | 7.73 | Conception | 0.13 |
| Montana | 70.2 | +4.6 | 5 stations | 110 | 27 | Bowen | 20 | 20 | 0.27 | −1.16 | Great Falls | 1.31 | 8 stations | 0.00 |
| Nebraska | 76.3 | +1.8 | Beaver City | 113 | 29 | Gordon | 38 | 16 | 1.17 | −2.27 | Harrison | 0.06 | Crete | 4.21 |
| Nevada | 74.5 | +2.8 | Logan | 111 | 12† | Gold Creek | 22 | 8† | 0.46 | +0.16 | Pioche | 2.15 | 9 stations | 0.00 |
| New England | 70.4 | +1.3 | Bridgeport, Conn | 102 | 31 | 2 stations in Vermont | 42 | 3† | 2.51 | −1.23 | Greenville, Me | 6.97 | Winslow, Me | 0.68 |
| New Jersey | 74.2 | +0.4 | Elizabeth | 104 | 31 | Layton | 46 | 1 | 4.83 | −0.08 | Indian Mills | 7.93 | Layton | 2.38 |
| New Mexico | 73.7 | +1.8 | 2 stations | 110 | 11† | Senorito (near) | 33 | 1 | 1.51 | −1.24 | Anchor Mine | 6.02 | 2 stations | 0.00 |
| New York | 70.8 | +0.6 | Rhinebeck | 102 | 30 | Indian Lake | 37 | 6 | 3.58 | −0.21 | Bolivar | 8.48 | Keene Valley | 0.59 |
| North Carolina | 76.1 | −0.3 | Lincolnton | 101 | 31 | Banners Elk | 44 | 2 | 7.73 | +2.07 | Winona | 13.30 | Cullowhee | 3.62 |
| North Dakota | 70.9 | +3.4 | Colgate | 114 | 28 | Marstonmoor | 27 | 3 | 1.66 | −0.95 | Willow City | 3.66 | Buford | 0.14 |
| Ohio | 72.3 | −1.3 | Danbury | 103 | 31 | Medina | 43 | 5 | 3.88 | −0.10 | Thurman | 7.66 | Danbury | 0.41 |
| Oklahoma | 83.3 | +2.6 | 2 stations | 114 | 13 | Vinita | 54 | 12 | 2.57 | −0.64 | Webbers Falls | 7.38 | Waukomis | 0.60 |
| Oregon | 69.6 | +2.8 | Umatilla | 114 | 16 | Crescent | 22 | 29 | 0.09 | −0.47 | Siskiyou | 1.06 | 41 stations | 0.00 |
| Pennsylvania | 72.0 | 0.0 | Carlisle | 105 | 31 | Warren | 40 | 4 | 4.33 | −0.09 | Bloserville | 9.76 | Le Roy | 1.90 |
| Porto Rico | 79.2 | +0.4 | Canovanas | 96 | 22 | Cayey | 61 | 4 | 5.69 | −0.91 | Anasco | 15.64 | Destino | 1.15 |
| South Carolina | 79.9 | 0.0 | Calhoun Falls | 102 | 9† | Mountain Rest | 52 | 10 | 6.56 | +0.72 | Ferguson | 11.41 | Greenwood | 2.26 |
| South Dakota | 74.3 | +2.5 | 3 stations | 111 | 28 | 2 stations | 32 | 3 | 1.48 | −1.10 | Armour | 4.29 | Vale | T. |
| Tennessee | 76.4 | −0.9 | Brownsville | 100 | 1 | Mountain City | 46 | 5 | 6.77 | +2.30 | Knoxville | 13.16 | Dyersburg | 2.54 |
| Texas | 84.6 | +2.0 | 2 stations | 114 | 10† | Claytonville | 49 | 17 | 2.27 | −0.56 | Long Lake | 9.51 | 3 stations | 0.00 |
| Utah | 73.5 | +2.7 | Hanksville | 112 | 13 | Pineview | 29 | 1 | 1.29 | +0.32 | Payson | 4.45 | 2 stations | T. |
| Virginia | 74.9 | −1.0 | Diamond Springs | 102 | 31 | Burkes Garden | 39 | 5 | 6.10 | +1.47 | Diamond Springs | 13.57 | Lynchburg | 2.97 |
| Washington | 67.2 | +1.2 | Rock Island | 109 | 18 | Wilbur | 25 | 29 | 0.18 | −0.58 | Silverton | 2.25 | 18 stations | 0.00 |
| West Virginia | 72.6 | −0.7 | Moorefield | 104 | 30† | Marlinton | 44 | 5 | 4.83 | +0.24 | Harpers Ferry | 8.27 | Moorefield | 1.25 |
| Wisconsin | 69.9 | +0.9 | Florence | 104 | 29 | Big St. Germain Dam. | 33 | 4 | 2.81 | −1.04 | Viroqua | 11.42 | Cecil | 0.24 |
| Wyoming | 66.9 | +3.0 | Colony | 108 | 27 | Afton | 18 | 31 | 0.56 | −0.81 | Boyd | 2.60 | 3 stations | 0.00 |

† Other dates also.

## DESCRIPTION OF TABLES AND CHARTS.

(Revised and corrected, September 1, 1917.)

Table I gives the data ordinarily needed for climatological studies for about 158 Weather Bureau stations making simultaneous observations at 8 a. m. and 8 p. m. daily, 75th meridian time, and for about 41 others making only one observation. The altitudes of the instruments above ground are also given.

Table II gives a record of precipitation, the intensity of which at some period of the storm's continuance equaled or exceeded the following rates:

| Duration (minutes)..... | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 60 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rates per hour (inches).... | 3.00 | 1.80 | 1.40 | 1.20 | 1.08 | 1.00 | 0.94 | 0.90 | 0.87 | 0.84 | 0.80 |

It is impracticable to make this table sufficiently wide to accommodate on one line the record of accumulated falls that continue at an excessive rate for several hours. In this case *the record is broken at the end of each 50 minutes*, the accumulated amounts being recorded on successive lines until the excessive rate ends.

In cases where no storm of sufficient intensity to entitle it to a place in the full table has occurred, the greatest precipitation of any single storm has been given; also the greatest hourly fall during that storm.

The tipping-bucket mechanism is *dismounted* and removed when there is danger of snow or water freezing in the same. Table II records this condition by entering an asterisk (*).

Table III gives, for about 30 stations of the Canadian Meteorological Service, the means of pressure and temperature, total precipitation and depth of snowfall, and the respective departures from normal values except in the case of snowfall. The sealevel pressures have been computed at Washington by the method employed for reducing United States observations and described by Prof. F. H. Bigelow in this REVIEW, January, 1902, pages 13–16; the altitudes are those furnished us on January 1, 1916.

Chart I.—*Hydrographs* for several of the principal rivers of the United States.

Chart II.—*Tracks of centers* of HIGH areas; and

Chart III.—*Tracks of centers* of LOW areas. The roman numerals show the chronological order of the centers. The figures within the circles show the days of the month; the letters *a* and *p* indicate, respectively, the observations at 8 a. m. and 8 p. m., 75th meridian time. Within each circle is also given (Chart II) the last three figures of the highest barometric reading, or (Chart III) the lowest reading reported at or near the center at that time, and in both cases as reduced to sealevel and standard gravity.

Chart IV.—*Temperature departures.* This chart presents the departures of the monthly mean surface temperatures from the monthly normals. The normals used in computing the departures were computed for a period of 33 years (1873 to 1905) and are published in Weather Bureau Bulletin R, Washington, 1908. Stations whose records were too short to justify the preparation of normals in 1908, have been provided with normals as adequate records became available, and all have been reduced to the 33-year interval 1873–1905. The shaded portions of the chart indicate areas of positive departures and unshaded portions indicate areas of negative departures. Generalized lines connect places having approximately equal departures of like sign. This chart of monthly surface temperature departures in the United States was first published in the MONTHLY WEATHER REVIEW for July, 1909.

Chart V.—*Total precipitation.* The scale of shades showing the depth is given on the chart. Where the monthly amounts are too small to justify shading and over sections of the country where stations are too widely separated or the topography is too diversified to warrant reasonable accuracy in shading, the actual depths are given for a limited number of representative stations. Amounts less than 0.005 inch are indicated by the letter T, and no precipitation by 0.

Chart VI.—*Percentage of clear sky between sunrise and sunset.* The average cloudiness at each Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the nighttime.

Chart VII.—*Isobars and isotherms at sealevel, and prevailing wind directions.* The pressures have been reduced to sealevel and standard gravity by the method described by Prof. Frank H. Bigelow on pages 13–16 of the REVIEW for January, 1902. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of the 8 a. m. and 8 p. m. readings at stations taking two observations daily, and to the 8 a. m. or the 8 p. m. observation, respectively, at stations taking but a single observation. The diurnal corrections so applied will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, Table 27, pages 140–164.

The isotherms on the sealevel plane have been constructed by means of the data summarized in chapter 8 of volume 2 of the annual report just mentioned. The correction, $t_0 - t$, or temperature on the sealevel plane minus the station temperature as given by Table 48 of that report, is added to the observed surface temperature to obtain the adopted sealevel temperature.

The prevailing wind directions are determined from hourly observations at the great majority of the stations. A few stations having no self-recording wind-direction apparatus determine the prevailing direction from the daily or twice-daily observations only.

Chart VIII.—*Total snowfall.* This is based on the reports from regular and cooperative observers and shows the depth in inches of the snowfall during the month. In general, the depth is shown by lines inclosing areas of equal snowfall, but in special cases figures are also given. Chart VIII is published only when the general snow cover is sufficiently extensive to justify its preparation.

Chart IX.—Average values of pressure, temperature, and prevailing wind directions, and storm tracks over the North Atlantic Ocean *for the corresponding month of last year.*

Chart X.—Presents *annually* the tracks of *hurricanes of the year;* tracks of the same month are all in one color. This chart was first published in the issue for September, 1916.

Chart XI.—Presents *annually,* by means of a dot for each report, the *frequency of earthquakes* in the United States during the year. This chart was first published in the REVIEW for December, 1915.

TABLE I.—*Climatological data for Weather Bureau stations, July, 1917.*

| Districts and stations. | Elevation of instruments. | | | Pressure. | | | Temperature of the air. | | | | | | | | | | | | Mean wet thermometer. | Mean temperature of the dew point. | Mean relative humidity. | Precipitation. | | | Wind. | | | | | | Clear days. | Partly cloudy days. | Cloudy days. | Average cloudiness, tenths. | Total snowfall. | Snow on ground at end of month. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barometer above sealevel. | Thermometer above ground. | Anemometer above ground. | Station, reduced to mean of 24 hours. | Sealevel, reduced to mean of 24 hours. | Departure from normal. | Mean max.+mean min.÷2. | Departure from normal. | Maximum. | Date. | Mean maximum. | Minimum. | Date. | Mean minimum. | Greatest daily range. | | | | | | | Total. | Departure from normal. | Days with 0.01 inch or more. | Total movement. | Prevailing direction. | Maximum velocity. Miles per hour. | Maximum velocity. Direction. | Maximum velocity. Date. | | | | | | |
| | Ft. | Ft. | Ft. | In. | In. | In. | °F. | °F. | °F. | | °F | °F. | | °F | °F. | °F. | °F. | % | In. | In. | | Miles | | | | | | | | | 0–10 | In. | In. |
| *New England.* | | | | | | | 69.7 | +0.8 | | | | | | | | | | 82 | 2.35 | −1.2 | | | | | | | | | | | 5.8 | | |
| Eastport | 76 | 67 | 85 | 29.85 | 29.93 | 0.00 | 58.4 | −1.4 | 84 | 31 | 68 | 45 | 23 | 49 | 32 | 56 | 54 | 90 | 1.90 | −1.5 | 11 | 5,165 | s. | 24 | ne. | 10 | 5 | 14 | 12 | 6.2 | | |
| Greenville | 1,070 | 6 | .... | 28.79 | 29.94 | ..... | 66.4 | ..... | 90 | 26 | 77 | 48 | 5 | 56 | 32 | ..... | ..... | ..... | 6.97 | ..... | 17 | ..... | ..... | ..... | ..... | ..... | 12 | 14 | 5 | ..... | ..... | ..... |
| Portland, Me | 103 | 82 | 117 | 29.83 | 29.95 | .00 | 68.8 | +0.8 | 92 | 31 | 78 | 54 | 12 | 60 | 26 | 63 | 60 | 78 | 1.92 | −1.3 | 12 | 5,468 | s. | 26 | nw. | 27 | 10 | 8 | 13 | 5.5 | ..... | ..... |
| Concord | 404 | 11 | 48 | 29.50 | 29.93 | − .01 | 71.4 | +2.3 | 98 | 30 | .... | 51 | 6 | .... | 33 | ..... | ..... | ..... | 1.27 | −2.5 | 7 | 3,137 | sw. | 30 | n. | 24 | 12 | 16 | 3 | 4.2 | ..... | ..... |
| Burlington | 288 | 70 | 79 | 29.64 | 29.95 | − .01 | 70.9 | +1.7 | 94 | 30 | 80 | 50 | 5 | 62 | 28 | ..... | ..... | ..... | 1.88 | −1.9 | 15 | 6,204 | s. | 26 | s. | 1 | 8 | 14 | 9 | 5.8 | ..... | ..... |
| Northfield | 876 | 12 | 60 | 29.02 | 29.95 | + .01 | 67.8 | +1.2 | 94 | 30 | 80 | 43 | 5 | 56 | 38 | 63 | 61 | 79 | 3.08 | −0.6 | 7 | 6,603 | sw. | 36 | ne. | 22 | 2 | 22 | 7 | 5.9 | ..... | ..... |
| Boston | 125 | 115 | 188 | 29.82 | 29.95 | − .01 | 73.3 | +2.0 | 98 | 30 | 81 | 56 | 10 | 66 | 25 | 67 | 65 | 77 | 1.10 | −2.3 | 13 | 4,126 | s. | 48 | sw. | 13 | 5 | 14 | 12 | 6.5 | ..... | ..... |
| Nantucket | 12 | 14 | 90 | 29.96 | 29.97 | − .01 | 67.5 | 0.0 | 90 | 31 | 74 | 54 | 12 | 61 | 21 | 64 | 64 | 92 | 3.32 | +0.6 | 10 | 11,039 | sw. | 34 | e. | 11 | 7 | 8 | 16 | 6.4 | ..... | ..... |
| Block Island | 26 | 11 | 46 | 29.94 | 29.97 | .00 | 68.4 | +0.3 | 89 | 31 | 74 | 56 | 10 | 63 | 22 | 66 | 66 | 94 | 2.90 | −0.4 | 9 | 10,811 | sw. | ..... | ..... | ..... | 17 | 6 | 8 | ..... | ..... | ..... |
| Narragansett Pier | .... | 9 | .... | ..... | ..... | ..... | 69.0 | −0.9 | 97 | 31 | 76 | 53 | 10 | 62 | 24 | ..... | ..... | ..... | 1.79 | ..... | 13 | ..... | sw. | 38 | sw. | 14 | 7 | 15 | 9 | 5.9 | ..... | ..... |
| Providence | 160 | 215 | 251 | 29.79 | 29.96 | − .01 | 73.6 | +0.2 | 100 | 31 | 82 | 54 | 10 | 65 | 25 | 66 | 63 | 76 | 1.09 | −2.4 | 6 | 7,387 | sw. | 35 | sw. | 2 | 5 | 14 | 12 | 6.0 | ..... | ..... |
| Hartford | 159 | 122 | 140 | 29.79 | 29.96 | − .01 | 73.6 | +2.0 | 97 | 31 | 82 | 57 | 6 | 65 | 28 | 67 | 64 | 78 | 4.07 | 0.0 | 10 | 5,094 | s. | 34 | nw. | 27 | 8 | 13 | 10 | 5.9 | ..... | ..... |
| New Haven | 106 | 117 | 155 | 29.86 | 29.97 | .00 | 73.2 | +1.3 | 99 | 31 | 81 | 58 | 12 | 66 | 29 | 67 | 64 | 78 | 3.35 | −1.4 | 12 | 5,642 | s. | ..... | ..... | ..... | ..... | ..... | ..... | 6.3 | ..... | ..... |
| *Middle Atlantic States.* | | | | | | | 74.6 | −0.1 | | | | | | | | | | 79 | 5.03 | +0.7 | | | | | | | | | | 4.9 | ..... | ..... |
| Albany | 97 | 102 | 115 | 29.84 | 29.94 | −0.02 | 73.4 | +1.4 | 99 | 30 | 82 | 55 | 5 | 64 | 29 | 66 | 62 | 73 | 1.70 | −2.2 | 9 | 4,488 | s. | 22 | s. | 18 | 9 | 16 | 6 | 6.3 | ..... | ..... |
| Binghamton | 871 | 10 | 69 | 29.04 | 29.95 | − .02 | 71.6 | +1.7 | 94 | 31 | 81 | 52 | 1 | 62 | 27 | ..... | ..... | ..... | 3.55 | 0.0 | 18 | 2,805 | sw. | 19 | nw. | 15 | 6 | 13 | 12 | 7.1 | ..... | ..... |
| New York | 314 | 414 | 454 | 29.64 | 29.97 | − .01 | 74.1 | +0.6 | 98 | 31 | 81 | 58 | 11 | 67 | 22 | 67 | 65 | 78 | 5.96 | +1.4 | 10 | 9,914 | sw. | 50 | sw. | 2 | 3 | 13 | 15 | 7.0 | ..... | ..... |
| Harrisburg | 374 | 94 | 104 | 29.58 | 29.97 | − .01 | 74.7 | +0.2 | 100 | 31 | 83 | 58 | 1 | 67 | 27 | 67 | 64 | 74 | 3.12 | −0.8 | 12 | 4,031 | sw. | 28 | sw. | 14 | 3 | 11 | 17 | 7.0 | ..... | ..... |
| Philadelphia | 117 | 123 | 190 | 29.86 | 29.98 | .00 | 76.4 | +0.6 | 101 | 31 | 84 | 60 | 12 | 69 | 24 | 69 | 66 | 75 | 5.63 | +1.3 | 11 | 6,667 | sw. | 29 | se. | 10 | 5 | 9 | 17 | 6.8 | ..... | ..... |
| Reading | 325 | 81 | 98 | 29.63 | 29.97 | ..... | 75.5 | ..... | 99 | 31 | 84 | 58 | 1 | 67 | 30 | 68 | 64 | 74 | 2.76 | −1.5 | 11 | 4,254 | s. | 32 | n. | 14 | 5 | 9 | 17 | 6.7 | ..... | ..... |
| Scranton | 805 | 111 | 119 | 29.13 | 29.98 | .00 | 72.7 | +0.9 | 98 | 31 | 82 | 52 | 1 | 64 | 26 | 67 | 65 | 82 | 2.27 | −1.6 | 14 | 3,932 | sw. | 24 | sw. | 14 | 4 | 12 | 10 | 6.8 | ..... | ..... |
| Atlantic City | 52 | 37 | 48 | 29.93 | 29.98 | .00 | 73.1 | +0.6 | 99 | 31 | 78 | 60 | 2 | 68 | 21 | 69 | 68 | 87 | 4.35 | +0.6 | 12 | 4,983 | sw. | 25 | sw. | 12 | 7 | 15 | 8 | 5.6 | ..... | ..... |
| Cape May | 18 | 13 | 49 | 30.00 | 30.02 | ..... | 73.2 | −0.2 | 98 | 31 | 80 | 61 | 3 | 67 | 24 | 69 | ..... | ..... | 5.81 | +2.0 | 12 | 4,743 | s. | 30 | nw. | 14 | 7 | 16 | 8 | 5.6 | ..... | ..... |
| Sandy Hook | 22 | 10 | 57 | 29.95 | 29.97 | ..... | 73.3 | ..... | 98 | 31 | 79 | 60 | 3 | 67 | 25 | 69 | 67 | 85 | 6.59 | ..... | 13 | 8,783 | sw. | 71 | s. | 2 | 5 | 15 | 11 | 5.9 | ..... | ..... |
| Trenton | 190 | 159 | 183 | 29.77 | 29.97 | ..... | 75.1 | ..... | 98 | 31 | 83 | 59 | 12 | 67 | 28 | 68 | 66 | 79 | 4.24 | −0.5 | 14 | 7,060 | sw. | 52 | w. | 2 | 5 | 15 | 11 | 7.0 | ..... | ..... |
| Baltimore | 123 | 100 | 113 | 29.85 | 29.97 | − .01 | 77.2 | −0.1 | 99 | 31 | 84 | 63 | 10 | 70 | 24 | 70 | 67 | 77 | 7.09 | +2.3 | 15 | 4,495 | s. | 26 | nw. | 12 | 4 | 14 | 13 | 6.5 | ..... | ..... |
| Washington | 112 | 62 | 85 | 29.86 | 29.97 | − .03 | 76.6 | −0.2 | 99 | 31 | 85 | 62 | 11 | 68 | 27 | 70 | 68 | 80 | 9.41 | +4.8 | 14 | 3,569 | sw. | 44 | nw. | 14 | 6 | 14 | 11 | 6.2 | ..... | ..... |
| Lynchburg | 681 | 153 | 188 | 29.27 | 29.99 | − .02 | 76.4 | −0.9 | 98 | 31 | 86 | 59 | 1 | 67 | 33 | 69 | 66 | 78 | 2.97 | −1.1 | 12 | 4,098 | w. | 33 | nw. | 16 | 7 | 10 | 14 | 6.1 | ..... | ..... |
| Norfolk | 91 | 170 | 205 | 29.91 | 30.01 | + .01 | 77.2 | −1.2 | 98 | 31 | 85 | 64 | 10 | 69 | 24 | 71 | 69 | 82 | 11.73 | +5.9 | 22 | 7,873 | s. | 66 | nw. | 16 | 7 | 13 | 11 | 5.9 | ..... | ..... |
| Richmond | 144 | 11 | 52 | 29.85 | 30.00 | − .01 | 76.8 | −2.4 | 96 | 31 | 86 | 62 | 11 | 68 | 24 | 70 | 69 | 83 | 6.28 | +1.9 | 17 | 4,932 | s. | 41 | nw. | 14 | 5 | 7 | 19 | 6.9 | ..... | ..... |
| Wytheville | 2,293 | 49 | 55 | 27.69 | 29.99 | − .02 | 70.6 | −2.0 | 90 | 31 | 80 | 50 | 5 | 61 | 35 | 64 | 62 | 80 | 3.68 | −0.8 | 14 | 3,615 | w. | 26 | sw. | 14 | 10 | 11 | 10 | 5.3 | ..... | ..... |
| *South Atlantic States.* | | | | | | | 78.9 | −0.2 | | | | | | | | | | 5.6 | | | | | | | | | | | | | | | |
| Asheville | 2,255 | 70 | 84 | 27.74 | 30.02 | 0.00 | 72.0 | +0.3 | 91 | 31 | 82 | 55 | 5 | 62 | 30 | 65 | 63 | 82 | 7.31 | +1.3 | | | | | | | | | | | | | | | |
| Charlotte | 773 | 153 | 161 | 29.19 | 30.01 | − .01 | 77.4 | −1.3 | 97 | 31 | 86 | 63 | 5 | 69 | 24 | 70 | 68 | 78 | 3.84 | −1.0 | 16 | 3,901 | se. | 31 | n. | 12 | 6 | 15 | 10 | 5.9 | ..... | ..... |
| Hatteras | 11 | 12 | 50 | 30.02 | 30.03 | + .02 | 78.4 | −0.2 | 91 | 31 | 83 | 69 | 11 | 74 | 14 | 75 | 73 | 88 | 5.85 | +0.4 | 13 | 5,899 | sw. | 37 | sw. | 15 | 6 | 12 | 13 | 6.5 | ..... | ..... |
| Manteo | 12 | 5 | 43 | ..... | ..... | ..... | 77.2 | ..... | 96 | 30 | 86 | 58 | 29 | 69 | ..... | ..... | ..... | ..... | 3.83 | −2.3 | 16 | 10,223 | sw. | 38 | sw. | 12 | 10 | 13 | 8 | 5.5 | ..... | ..... |
| Raleigh | 376 | 103 | 110 | 29.62 | 30.00 | − .02 | 77.8 | −0.7 | 98 | 31 | 87 | 63 | 5 | 69 | 25 | 71 | 69 | 82 | 7.86 | +1.8 | 11 | ..... | sw. | ..... | ..... | ..... | ..... | 17 | 3 | 11 | ..... | ..... |
| Wilmington | 78 | 81 | 91 | 29.95 | 30.03 | + .02 | 78.9 | +0.2 | 97 | 31 | 86 | 67 | 1 | 72 | 21 | 73 | 72 | 84 | 12.37 | +5.4 | 19 | 3,830 | sw. | 26 | sw. | 12 | 9 | 14 | 8 | 5.3 | ..... | ..... |
| Charleston | 48 | 11 | 92 | 29.99 | 30.04 | + .01 | 80.8 | −0.5 | 95 | 28 | 87 | 66 | 8 | 74 | 21 | 75 | 74 | 80 | 9.95 | +2.7 | 17 | 5,408 | sw. | 34 | e. | 27 | 9 | 10 | 12 | 5.4 | ..... | ..... |
| Columbia, S. C. | 351 | 41 | 57 | 29.65 | 30.03 | + .01 | 80.5 | −0.6 | 96 | 31 | 89 | 66 | 17 | 72 | 25 | 71 | 69 | 78 | 4.41 | −1.6 | 16 | 7,087 | s. | 46 | ne. | 8 | 11 | 14 | 6 | 4.8 | ..... | ..... |
| Augusta | 180 | 62 | 77 | 29.82 | 30.01 | − .01 | 81.0 | +0.5 | 96 | 31 | 91 | 67 | 17 | 71 | 26 | 73 | 71 | 78 | 5.75 | +0.5 | 14 | 4,730 | sw. | 45 | sw. | 17 | 9 | 10 | 12 | 5.6 | ..... | ..... |
| Savannah | 65 | 150 | 194 | 29.97 | 30.04 | + .01 | 81.2 | +0.7 | 96 | 27 | 89 | 68 | 13 | 73 | 23 | 74 | 73 | 83 | 8.39 | +2.2 | 12 | 3,680 | se. | 39 | w. | 17 | 11 | 9 | 11 | 5.4 | ..... | ..... |
| Jacksonville | 43 | 200 | 245 | 30.01 | 30.06 | + .03 | 81.0 | +0.1 | 94 | 31 | 89 | 69 | 4 | 73 | 23 | 74 | 72 | 83 | 10.36 | +4.2 | 17 | 5,997 | sw. | 44 | w. | 7 | 4 | 16 | 11 | 6.2 | ..... | ..... |
| *Florida Peninsula.* | | | | | | | 82.1 | +0.2 | | | | | | | | | | 75 | 3.50 | −2.9 | 17 | 8,276 | sw. | 60 | sw. | 14 | 9 | 16 | 6 | 5.2 | ..... | ..... |
| Key West | 22 | 10 | 64 | 30.02 | 30.04 | +0.01 | 83.4 | −0.3 | 91 | 30 | 88 | 74 | 10 | 79 | 16 | 75 | 72 | 72 | 0.80 | −2.8 | 11 | 6,818 | se. | 36 | sw. | 10 | 18 | 12 | 1 | 3.3 | ..... | ..... |
| Miami | 25 | 71 | 79 | 30.05 | 30.08 | ..... | 81.0 | −0.9 | 89 | 11 | 86 | 67 | 10 | 76 | 21 | 75 | 72 | 75 | 2.48 | −4.8 | 10 | 5,652 | e. | 36 | sw. | 10 | 14 | 11 | 6 | 4.5 | ..... | ..... |
| Sand Key | 23 | 39 | 72 | 30.00 | 30.03 | .00 | 81.8 | ..... | 89 | 30 | 84 | 72 | 25 | 79 | 12 | 76 | 73 | 75 | 0.93 | ..... | 8 | 8,946 | e. | 46 | s. | 10 | 18 | 13 | 0 | 3.1 | ..... | ..... |
| Tampa | 35 | 79 | 92 | 30.03 | 30.06 | + .02 | 81.9 | +1.9 | 94 | 16 | 90 | 68 | 13 | 74 | 25 | 74 | 72 | 78 | 7.21 | −1.2 | 21 | 4,473 | se. | 26 | se. | 14 | 2 | 25 | 4 | 5.6 | ..... | ..... |
| *East Gulf States.* | | | | | | | 80.2 | −0.1 | | | | | | | | | | 78 | 5.69 | +0.4 | | | | | | | | | | 5.5 | | |
| Atlanta | 1,174 | 190 | 216 | 28.82 | 30.03 | +0.01 | 78.0 | +0.4 | 93 | 31 | 87 | 65 | 17 | 69 | 23 | 70 | 67 | 75 | 1.98 | −2.8 | 12 | 6,615 | w. | 48 | e. | 31 | 10 | 7 | 14 | 5.6 | ..... | ..... |
| Macon | 370 | 78 | 87 | 29.65 | 30.04 | + .02 | 80.6 | +0.9 | 97 | 31 | 91 | 67 | 12 | 70 | 24 | 72 | 69 | 75 | 4.54 | −0.1 | 15 | 3,791 | s. | 36 | s. | 13 | 8 | 13 | 10 | 5.8 | ..... | ..... |
| Thomasville | 273 | 49 | 58 | 29.75 | 30.04 | + .01 | 80.4 | −1.4 | 95 | 28 | 90 | 67 | 14 | 71 | 27 | 73 | 72 | 82 | 9.11 | +3.8 | 17 | 2,742 | sw. | 19 | n. | 25 | 3 | 19 | 9 | 6.3 | ..... | ..... |
| Pensacola | 56 | 149 | 185 | 29.98 | 30.04 | + .03 | 80.0 | −1.4 | 91 | 29 | 85 | 68 | 7 | 75 | 19 | 75 | 73 | 81 | 3.96 | −3.3 | 13 | 7,935 | sw. | 44 | n. | 6 | 5 | 13 | 13 | 6.5 | ..... | ..... |
| Anniston | 741 | 9 | 57 | 29.26 | 30.04 | + .02 | 77.6 | −0.3 | 94 | 31 | 88 | 64 | 11 | 70 | 26 | 71 | 69 | 80 | 5.03 | +0.3 | 15 | 2,953 | s. | 23 | sw. | 16 | 8 | 19 | 4 | 4.8 | ..... | ..... |
| Birmingham | 700 | 11 | 48 | 29.29 | 30.04 | + .03 | 79.5 | −2.0 | 96 | 31 | 89 | 67 | 6 | 74 | 23 | 74 | 72 | 78 | 3.71 | −1.0 | 16 | 3,665 | s. | 30 | w. | 10 | 5 | 16 | 10 | 5.8 | ..... | ..... |
| Mobile | 57 | 125 | 161 | 29.97 | 30.03 | + .02 | 81.4 | +0.9 | 96 | 30 | 89 | 67 | 6 | 74 | 23 | 72 | 70 | 79 | 10.54 | +3.5 | 18 | 6,269 | sw. | 50 | n. | 6 | 5 | 17 | 9 | 5.8 | ..... | ..... |
| Montgomery | 223 | 100 | 112 | 29.79 | 30.03 | + .01 | 80.4 | −0.6 | 95 | 31 | 90 | 66 | 22 | 71 | 23 | ..... | ..... | ..... | 5.26 | +0.6 | 15 | 3,768 | s. | 35 | nw. | 2 | 7 | 14 | 10 | 5.8 | ..... | ..... |
| Corinth | 469 | 6 | .... | ..... | ..... | ..... | 79.0 | ..... | 98 | 31 | 90 | 60 | 11 | 68 | 33 | ..... | ..... | ..... | 7.52 | ..... | 13 | ..... | s. | ..... | ..... | ..... | ..... | 7 | 21 | 3 | ..... | ..... | ..... |
| Jackson | 304 | 5 | .... | ..... | ..... | ..... | 82.7 | ..... | 101 | 13 | 94 | 68 | 10 | 71 | 31 | ..... | ..... | ..... | 2.98 | ..... | 8 | ..... | sw. | ..... | ..... | ..... | ..... | 7 | 19 | 5 | ..... | ..... | ..... |
| Meridian | 375 | 85 | 93 | 29.62 | 30.00 | − .02 | 80.5 | +0.5 | 96 | 1 | 90 | 67 | 6 | 71 | 25 | 72 | 69 | 77 | 5.12 | +0.6 | 14 | 3,467 | sw. | 33 | nw. | 6 | 12 | 13 | 6 | 4.5 | ..... | ..... |
| Vicksburg | 247 | 65 | 74 | 29.74 | 30.02 | + .02 | 80.8 | +0.4 | 96 | 1 | 90 | 67 | 19 | 72 | 26 | 73 | 71 | 76 | 4.97 | +0.6 | 9 | 4,190 | sw. | 27 | ne. | 7 | 17 | 5 | 9 | 3.9 | ..... | ..... |
| New Orleans | 51 | 76 | 84 | 29.97 | 30.02 | + .02 | 82.6 | +1.3 | 98 | 10 | 91 | 68 | 18 | 75 | 24 | 75 | 73 | 79 | 8.35 | +1.9 | 14 | 4,097 | sw. | 38 | ne. | 7 | 5 | 15 | 11 | 6.1 | ..... | ..... |
| *West Gulf States.* | | | | | | | 82.7 | +0.8 | | | | | | | | | | 69 | 3.73 | +0.6 | | | | | | | | | | 3.6 | | |
| Shreveport | 249 | 77 | 93 | 29.72 | 29.99 | +0.01 | 83.3 | +1.2 | 103 | 10 | 94 | 67 | 16 | 73 | 31 | 72 | 68 | 66 | 9.30 | +5.6 | 6 | 4,634 | s. | 24 | se. | 8 | 22 | 7 | 2 | 2.9 | ..... | ..... |
| Bentonville | 1,303 | 11 | 44 | 28.62 | 29.96 | − .01 | 77.3 | −1.2 | 98 | 7 | 89 | 57 | 3 | 66 | 31 | ..... | ..... | ..... | 5.66 | +1.4 | 9 | 3,575 | s. | 20 | nw | 14 | 22 | 7 | 2 | 3.1 | ..... | ..... |
| Fort Smith | 457 | 79 | 94 | 29.47 | 29.94 | − .03 | 81.8 | +0.8 | 103 | 1 | 93 | 65 | 13 | 71 | 36 | 71 | 67 | 66 | 2.00 | −1.8 | 11 | 4,896 | e. | 30 | sw. | 23 | 12 | 12 | 7 | 4.5 | ..... | ..... |
| Little Rock | 357 | 139 | 147 | 29.60 | 29.97 | − .02 | 80.1 | −0.5 | 99 | 7 | 89 | 65 | 17 | 71 | 28 | 72 | 68 | 71 | 4.54 | +0.6 | 9 | 5,750 | s. | 44 | n. | 23 | 12 | 10 | 9 | 4.5 | ..... | ..... |
| Brownsville | 57 | 4 | 26 | ..... | ..... | ..... | 84.2 | ..... | 99 | 10 | 94 | 72 | 17 | 75 | 26 | ..... | ..... | ..... | 4.52 | ..... | 5 | ..... | se. | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Corpus Christi | 20 | 69 | 77 | 29.97 | 29.99 | + .03 | 82.2 | −0.5 | 92 | 10 | 87 | 73 | 21 | 77 | 17 | 77 | 75 | 83 | 0.95 | −0.7 | 1 | 11,366 | se. | 46 | se. | 21 | 14 | 13 | 4 | 4.3 | ..... | ..... |
| Dallas | 512 | 109 | 117 | 29.42 | 29.95 | ..... | 84.7 | ..... | 104 | 10 | 94 | 68 | 16 | 75 | 31 | ..... | ..... | ..... | 2.35 | ..... | 8 | 6,811 | s. | 33 | s. | 14 | 14 | 12 | 5 | 4.4 | ..... | ..... |
| Fort Worth | 670 | 106 | 114 | 29.23 | 29.92 | − .04 | 84.6 | +0.9 | 107 | 10 | 95 | 68 | 4 | 74 | 31 | 70 | 64 | 56 | 2.65 | −0.4 | 5 | 7,588 | s. | 35 | s. | 14 | 15 | 10 | 6 | 4.0 | ..... | ..... |
| Galveston | 54 | 106 | 114 | 29.96 | 30.02 | + .04 | 83.3 | +0.3 | 93 | 12 | 87 | 73 | 20 | 79 | 18 | 76 | 74 | 78 | 0.46 | −3.5 | 7 | 5,689 | s. | 26 | sw. | 11 | 17 | 13 | 1 | 3.1 | ..... | ..... |
| Houston | 138 | 111 | 121 | 29.86 | 30.00 | ..... | 84.2 | +1.2 | 101 | 11 | 94 | 68 | 2 | 75 | 29 | ..... | ..... | ..... | 3.30 | ..... | 3 | 8,167 | s. | 32 | ne. | 3 | 19 | 12 | 0 | 3.2 | ..... | ..... |
| Palestine | 510 | 64 | 72 | 29.45 | 29.96 | − .01 | 83.4 | +1.9 | 105 | 10 | 94 | 65 | 16 | 73 | 28 | 73 | 68 | 69 | 7.73 | +4.7 | 6 | 5,193 | s. | 35 | ne. | 16 | 17 | 8 | 6 | 4.0 | ..... | ..... |
| Port Arthur, Tex | 34 | 58 | 66 | 29.96 | 30.00 | ..... | 82.8 | ..... | 97 | 10 | 90 | 68 | 4 | 76 | 22 | 78 | 77 | 87 | 6.42 | ..... | 13 | 6,866 | s. | 28 | sw. | 12 | 11 | 16 | 4 | 4.4 | ..... | ..... |
| San Antonio | 701 | 119 | 132 | 29.23 | 29.94 | − .01 | 84.8 | +2.4 | 104 | 11 | 96 | 68 | 20 | 73 | 30 | 72 | 66 | 64 | 2.19 | 0.0 | 4 | 6,046 | s. | 41 | nw. | 20 | 28 | 3 | 0 | 1.4 | ..... | ..... |
| Taylor | 582 | 55 | 63 | 29.39 | 30.00 | + .04 | 84.6 | +1.9 | 106 | 11 | 96 | 67 | 20 | 73 | 33 | ..... | ..... | ..... | 1.84 | −0.8 | 7 | 7,415 | s. | 38 | n. | 20 | 11 | 19 | 1 | 3.9 | ..... | ..... |

TABLE I.—*Climatological data for Weather Bureau stations, July, 1917*—Continued.

| Districts and stations. | Elevation of instruments. | | | Pressure. | | | Temperature of the air. | | | | | | | | | | Mean wet thermometer. | Mean temperature of the dew point. | Mean relative humidity. | Precipitation. | | | Wind. | | | | Clear days. | Partly cloudy days. | Cloudy days. | Average cloudiness, tenths. | Total snowfall. | Snow on ground at end of month. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barometer above sealevel. | Thermometer above ground. | Anemometer above ground. | Station, reduced to mean of 24 hours. | Sealevel, reduced to mean of 24 hours. | Departure from normal. | Mean max.+mean min.÷2. | Departure from normal. | Maximum. | Date. | Mean maximum. | Minimum. | Date. | Mean minimum. | Greatest daily range. | | | | | Total. | Departure from normal. | Days with 0.01 inch or more. | Total movement. | Prevailing direction. | Maximum velocity. Miles per hour. | Maximum velocity. Direction. | Maximum velocity. Date. | | | | | | |
| *Ohio Valley and Tennessee.* | *Ft.* | *Ft.* | *Ft.* | *In.* | *In.* | *In.* | *°F.* | *°F.* | *°F* | *°F* | *°F* | *°F* | *°F* | *°F* | *°F.* | | *°F.* | *°F.* | *%* | *In.* | *In.* | | *Miles* | | | | | | | | *0–10* | *In.* | *In.* |
| | | | | | | | 75.1 | −1.4 | | | | | | | | | | | 75 | 4.28 | +0.3 | | | | | | | | | 5.4 | | |
| Chattanooga | 762 | 189 | 213 | 29.22 | 30.01 | −0.01 | 77.0 | −0.8 | 94 | 31 | 86 | 63 | 11 | 69 | 26 | | 69 | 66 | 74 | 4.84 | +1.0 | 14 | 5,025 | w. | 46 | sw. | 15 | 5 | 18 | 8 | 5.9 | | |
| Knoxville | 996 | 102 | 111 | 28.97 | 30.00 | − .02 | 76.2 | 0.0 | 93 | 30 | 85 | 61 | 11 | 67 | 27 | | 70 | 68 | 80 | 13.16 | +9.0 | 13 | 3,701 | sw. | 31 | n. | 14 | 2 | 11 | 18 | 6.9 | | |
| Memphis | 399 | 76 | 97 | 29.59 | 30.01 | + .01 | 79.0 | −1.7 | 95 | 1 | 87 | 62 | 19 | 72 | 23 | | 72 | 69 | 75 | 5.96 | +2.4 | 12 | 5,441 | sw. | 64 | nw. | 19 | 16 | 10 | 5 | 4.0 | | |
| Nashville | 546 | 168 | 191 | 29.43 | 30.00 | − .01 | 77.2 | −2.2 | 95 | 14 | 87 | 60 | 13 | 68 | 30 | | 69 | 66 | 73 | 3.25 | −1.1 | 11 | 4,375 | sw. | 37 | n. | 14 | 9 | 13 | 9 | 5.4 | | |
| Lexington | 989 | 193 | 230 | 28.94 | 29.99 | − .02 | 74.4 | −2.2 | 92 | 31 | 82 | 58 | 11 | 66 | 22 | | | | | 2.80 | −1.6 | 14 | 7,631 | sw. | 30 | sw. | 13 | 11 | 14 | 6 | 5.0 | | |
| Louisville | 525 | 219 | 255 | 29.42 | 30.00 | .00 | 76.4 | −2.2 | 94 | 31 | 85 | 60 | 4 | 68 | 24 | | 68 | 64 | 69 | 1.86 | −1.9 | 13 | 6,847 | s. | 34 | s. | 13 | 9 | 12 | 10 | 5.7 | | |
| Evansville | 431 | 139 | 175 | 29.52 | 29.98 | − .02 | 78.2 | −1.1 | 94 | 1 | 87 | 63 | 4 | 69 | 26 | | 69 | 65 | 68 | 2.26 | −1.6 | 8 | 6,548 | s. | 41 | s. | 13 | 9 | 20 | 2 | 4.7 | | |
| Indianapolis | 822 | 194 | 230 | 29.10 | 29.97 | − .02 | 74.0 | −2.2 | 93 | 30 | 83 | 53 | 11 | 65 | 24 | | 66 | 62 | 69 | 3.20 | −0.9 | 9 | 6,599 | sw. | 33 | w. | 26 | 12 | 10 | 9 | 4.8 | | |
| Terre Haute | 575 | 96 | 129 | 29.34 | 29.95 | ..... | 75.6 | ..... | 94 | 30 | 85 | 55 | 4 | 66 | 27 | | 67 | 63 | 69 | 4.02 | ..... | 7 | 5,765 | sw. | 30 | nw. | 26 | 5 | 21 | 5 | 5.4 | | |
| Cincinnati | 628 | 11 | 51 | 29.31 | 29.97 | − .03 | 74.0 | +0.2 | 94 | 31 | 84 | 54 | 11 | 64 | 27 | | 67 | 64 | 76 | 4.04 | +0.5 | 16 | 3,949 | sw. | 25 | nw. | 1 | 9 | 12 | 10 | 5.7 | | |
| Columbus | 824 | 173 | 222 | 29.11 | 29.97 | − .03 | 73.6 | −1.7 | 95 | 31 | 83 | 57 | 13 | 64 | 28 | | 68 | 66 | 80 | 4.09 | +0.4 | 11 | 5,990 | sw. | 58 | w. | 1 | 15 | 8 | 8 | 4.2 | | |
| Dayton | 899 | 181 | 216 | 29.01 | 29.94 | ..... | 73.2 | −3.0 | 93 | 31 | 82 | 53 | 11 | 64 | 26 | | 68 | 65 | 79 | 3.34 | +0.1 | 10 | 5,771 | sw. | 37 | ne. | 23 | 8 | 15 | 11 | 5.8 | | |
| Pittsburgh | 842 | 353 | 410 | 29.08 | 29.97 | − .03 | 73.6 | −1.0 | 93 | 31 | 82 | 55 | 4 | 65 | 26 | | 66 | 62 | 72 | 2.33 | −2.1 | 11 | 6,773 | sw. | 40 | w. | 2 | 9 | 7 | 15 | 5.8 | | |
| Elkins | 1,940 | 41 | 50 | 28.00 | 29.99 | − .02 | 70.4 | −0.1 | 90 | 31 | 82 | 49 | 5 | 59 | 37 | | 63 | 61 | 81 | 2.6 | −2.0 | 17 | 2,174 | w. | 15 | w. | 7 | 2 | 11 | 18 | 7.1 | | |
| Parkersburg | 638 | 77 | 84 | 29.34 | 29.99 | − .02 | 74.4 | −1.2 | 94 | 31 | 84 | 57 | 3 | 65 | 30 | | 68 | 66 | 80 | 6.17 | +1.5 | 15 | 3,163 | sw. | 27 | nw. | 26 | 13 | 11 | 7 | 4.8 | | |
| *Lower Lake Region.* | | | | | | | 71.4 | −0.3 | | | | | | | | | | | 74 | 2.63 | −0.8 | | | | | | | | | 4.7 | | |
| Buffalo | 767 | 247 | 280 | 29.12 | 29.93 | −0.04 | 69.5 | −0.7 | 93 | 25 | 75 | 56 | 4 | 64 | 23 | | 64 | 62 | 79 | 4.46 | +1.1 | 11 | 10,320 | sw. | 72 | nw. | 9 | 13 | 11 | 7 | 4.9 | | |
| Canton | 448 | 10 | 61 | 29.44 | 29.91 | ..... | 70.0 | −0.5 | 93 | 31 | 79 | 49 | 4 | 61 | 28 | | | | | 2.23 | −1.0 | 10 | 6,421 | sw. | 37 | sw. | 30 | 15 | 11 | 5 | 4.1 | | |
| Oswego | 335 | 76 | 91 | 29.56 | 29.92 | − .04 | 70.1 | +0.5 | 92 | 30 | 77 | 54 | 5 | 63 | 22 | | 64 | 61 | 76 | 1.49 | −1.7 | 12 | 5,420 | s. | 25 | sw. | 30 | 8 | 12 | 11 | 5.4 | | |
| Rochester | 523 | 97 | 113 | 29.38 | 29.94 | − .03 | 71.7 | +1.3 | 93 | 30 | 80 | 52 | 4 | 63 | 23 | | 65 | 62 | 73 | 4.22 | +1.1 | 11 | 5,245 | sw. | 32 | sw. | 30 | 11 | 12 | 8 | 5.3 | | |
| Syracuse | 597 | 97 | 113 | 29.32 | 29.96 | − .01 | 71.1 | +0.3 | 93 | 30 | 79 | 51 | 4 | 63 | 25 | | 65 | 61 | 73 | 1.80 | −1.9 | 13 | 6,611 | s. | 31 | nw. | 21 | 8 | 15 | 8 | 5.5 | | |
| Erie | 714 | 130 | 166 | 29.18 | 29.93 | − .05 | 71.6 | −0.2 | 92 | 31 | 78 | 52 | 4 | 65 | 22 | | 66 | 62 | 74 | 4.33 | +1.1 | 9 | 9,013 | sw. | 44 | sw. | 13 | 17 | 10 | 4 | 3.8 | | |
| Cleveland | 762 | 190 | 201 | 29.14 | 29.95 | − .04 | 71.4 | −1.1 | 95 | 31 | 78 | 53 | 4 | 65 | 22 | | 65 | 62 | 76 | 3.60 | 0.0 | 12 | 7,418 | s. | 36 | n. | 27 | 16 | 10 | 5 | 4.5 | | |
| Sandusky | 629 | 62 | 103 | 29.28 | 29.95 | − .04 | 73.0 | −0.6 | 99 | 31 | 81 | 55 | 4 | 65 | 23 | | 66 | 62 | 72 | 0.46 | −3.3 | 7 | 7,271 | sw. | 34 | se. | 21 | 9 | 16 | 6 | 4.8 | | |
| Toledo | 628 | 208 | 243 | 29.28 | 29.95 | − .04 | 73.2 | −0.5 | 97 | 31 | 82 | 53 | 4 | 65 | 24 | | 66 | 62 | 72 | 1.51 | −1.7 | 10 | 8,644 | sw. | 41 | sw. | 1 | 17 | 11 | 3 | 3.8 | | |
| Fort Wayne | 856 | 113 | 124 | 29.06 | 29.96 | − .02 | 72.0 | −1.5 | 95 | 31 | 82 | 50 | 11 | 62 | 27 | | 65 | 62 | 74 | 4.98 | ..... | 11 | 5,645 | sw. | 31 | sw. | 6 | 9 | 18 | 4 | 4.7 | | |
| Detroit | 730 | 218 | 245 | 29.16 | 29.94 | − .04 | 72.2 | +0.2 | 95 | 31 | 80 | 53 | 4 | 64 | 20 | | 65 | 62 | 73 | 2.21 | −1.3 | 11 | 7,246 | sw. | 36 | sw. | 1 | 10 | 13 | 8 | 5.2 | | |
| *Upper Lake Region.* | | | | | | | 67.8 | 0.0 | | | | | | | | | | | 78 | 2.91 | −0.2 | | | | | | | | | 4.8 | | |
| Alpena | 609 | 13 | 92 | 29.26 | 29.92 | −0.05 | 66.6 | +0.8 | 101 | 29 | 75 | 46 | 5 | 58 | 30 | | 62 | 59 | 78 | 2.54 | −0.5 | 9 | 6,120 | se. | 38 | se. | 1 | 13 | 12 | 6 | 4.3 | | |
| Escanaba | 612 | 54 | 60 | 29.25 | 29.91 | − .06 | 65.9 | −0.7 | 90 | 30 | 74 | 45 | 3 | 58 | 25 | | 61 | 59 | 81 | 2.57 | −0.8 | 11 | 5,738 | s. | 28 | sw. | 29 | 10 | 15 | 6 | 4.6 | | |
| Grand Haven | 632 | 54 | 92 | 29.26 | 29.92 | − .06 | 68.0 | −1.7 | 92 | 25 | 75 | 48 | 10 | 61 | 24 | | 62 | 60 | 77 | 2.62 | 0.0 | 8 | 7,377 | w. | 37 | sw. | 1 | 18 | 7 | 6 | 3.4 | | |
| Grand Rapids | 707 | 70 | 87 | 29.18 | 29.93 | − .05 | 71.6 | −1.0 | 98 | 31 | 81 | 49 | 4 | 62 | 26 | | 65 | 62 | 74 | 6.91 | +4.3 | 11 | 3,909 | sw. | 23 | nw. | 2 | 12 | 11 | 8 | 4.6 | | |
| Houghton | 684 | 62 | 99 | 29.16 | 29.88 | − .08 | 65.4 | +0.1 | 103 | 29 | 76 | 45 | 10 | 55 | 34 | | | | | 2.51 | −0.6 | 9 | 6,765 | e. | 30 | nw. | 30 | 18 | 9 | 4 | 3.5 | | |
| Lansing | 878 | 11 | 62 | 29.01 | 29.93 | ..... | 70.0 | −1.1 | 96 | 31 | 80 | 47 | 4 | 60 | 30 | | 64 | 62 | 80 | 3.06 | −0.2 | 11 | 3,222 | sw. | 20 | s. | 1 | 12 | 9 | 10 | 5.4 | | |
| Ludington | 637 | 60 | 66 | 29.24 | 29.93 | ..... | 65.4 | ..... | 92 | 25 | 72 | 48 | 11 | 58 | 23 | | 63 | 61 | 88 | 1.58 | ..... | 8 | 6,589 | s. | 38 | w. | 1 | 13 | 13 | 5 | 4.3 | | |
| Marquette | 734 | 77 | 111 | 29.13 | 29.93 | − .05 | 64.6 | −0.3 | 105 | 29 | 73 | 45 | 4 | 56 | 29 | | 59 | 55 | 73 | 1.99 | −1.1 | 11 | 6,282 | nw. | 36 | sw. | 28 | 9 | 11 | 11 | 6.0 | | |
| Port Huron | 638 | 70 | 120 | 29.24 | 29.93 | − .05 | 69.6 | +0.6 | 96 | 29 | 78 | 50 | 3 | 61 | 23 | | 64 | 62 | 79 | 4.61 | +1.9 | 13 | 6,186 | sw. | 29 | nw. | 9 | 12 | 14 | 5 | 4.6 | | |
| Saginaw | 641 | 48 | 82 | 29.24 | 29.92 | ..... | 71.4 | ..... | 98 | 31 | 81 | 49 | 4 | 62 | 28 | | 65 | 62 | 75 | 2.04 | −1.7 | 12 | 5,363 | sw. | 33 | sw. | 20 | 8 | 8 | 15 | 6.4 | | |
| Sault Sainte Marie | 614 | 11 | 61 | 29.23 | 29.91 | − .06 | 63.0 | +1.1 | 95 | 31 | 74 | 43 | 4 | 52 | 40 | | 59 | 56 | 82 | 1.95 | −0.8 | 11 | 4,842 | w. | 31 | nw. | 10 | 6 | 13 | 12 | 6.0 | | |
| Chicago | 823 | 140 | 310 | 29.08 | 29.94 | − .04 | 72.2 | −0.2 | 98 | 30 | 79 | 55 | 10 | 65 | 26 | | 64 | 61 | 71 | 2.68 | −1.0 | 7 | 7,491 | sw. | 36 | w. | 2 | 15 | 8 | 8 | 4.3 | | |
| Green Bay | 617 | 109 | 144 | 29.25 | 29.90 | − .07 | 70.1 | +0.6 | 96 | 31 | 79 | 50 | 4 | 61 | 29 | | 64 | 61 | 75 | 1.52 | −2.0 | 10 | 7,156 | sw. | 40 | sw. | 1 | 7 | 18 | 6 | 5.7 | | |
| Milwaukee | 681 | 119 | 133 | 29.20 | 29.93 | − .04 | 70.2 | +0.5 | 98 | 30 | 78 | 53 | 11 | 63 | 27 | | 64 | 61 | 75 | 1.53 | −1.5 | 8 | 6,052 | sw. | 30 | nw. | 1 | 14 | 11 | 6 | 4.0 | | |
| Duluth | 1,133 | 11 | 47 | 28.70 | 29.90 | − .05 | 64.5 | +1.5 | 94 | 29 | 74 | 45 | 11 | 55 | 34 | | 60 | 57 | 78 | 4.29 | +0.6 | 12 | 6,839 | ne. | 54 | sw. | 29 | 14 | 8 | 9 | 4.5 | | |
| *North Dakota.* | | | | | | | 71.9 | +2.8 | | | | | | | | | | | 61 | 1.07 | −1.8 | | | | | | | | | 3.2 | | |
| Moorhead | 940 | 8 | 57 | 28.90 | 29.90 | −0.04 | 72.5 | +3.8 | 110 | 28 | 86 | 42 | 2 | 59 | 37 | | 64 | 61 | 71 | 0.81 | −2.9 | 8 | 5,360 | se. | 28 | nw. | 21 | 26 | 5 | 0 | 1.5 | | |
| Bismarck | 1,674 | 8 | 57 | 28.16 | 29.90 | − .03 | 73.2 | +3.0 | 107 | 28 | 87 | 44 | 3 | 60 | 40 | | 62 | 54 | 58 | 1.50 | −0.6 | 12 | 7,478 | nw. | 37 | nw. | 31 | 15 | 15 | 1 | 3.3 | | |
| Devils Lake | 1,482 | 11 | 44 | 28.32 | 29.86 | − .07 | 70.0 | +1.9 | 106 | 28 | 84 | 37 | 2 | 56 | 40 | | 60 | 55 | 63 | 1.60 | −2.2 | 16 | 7,034 | s. | 34 | w. | 29 | 6 | 15 | 7 | 4.8 | | |
| Grand Forks | 835 | 12 | 89 | ..... | ..... | ..... | 68.8 | ..... | 106 | 28 | 82 | 40 | 2 | 56 | 41 | | 65 | ..... | ..... | 2.84 | ..... | 7 | ..... | s. | 48 | nw. | 8 | 22 | 3 | 6 | ..... | | |
| Williston | 1,872 | 41 | 48 | 27.91 | 29.83 | − .09 | 72.1 | +2.7 | 106 | 27 | 87 | 39 | 2 | 58 | 41 | | 59 | 50 | 52 | 0.36 | −1.7 | 7 | 6,329 | se. | 40 | w. | 4 | 17 | 13 | 1 | 3.4 | | |
| *Upper Mississippi Valley.* | | | | | | | 75.2 | −0.2 | | | | | | | | | | | 70 | 3.40 | − 0.2 | | | | | | | | | 4.2 | | |
| Minneapolis | 918 | 10 | 208 | 28.93 | 29.89 | ..... | 73.0 | ..... | 99 | 28 | 82 | 52 | 2 | 64 | 24 | | ..... | ..... | ..... | 4.00 | +0.2 | 14 | 7,790 | se. | 44 | nw. | 30 | 17 | 10 | 6 | 3.9 | | |
| St. Paul | 837 | 201 | 236 | 29.00 | 29.89 | −0.06 | 72.4 | +0.3 | 99 | 28 | 82 | 49 | 4 | 63 | 26 | | ..... | ..... | ..... | 4.12 | +0.7 | 14 | 7,692 | se. | 46 | nw. | 30 | 11 | 14 | 5 | 4.3 | | |
| La Crosse | 714 | 11 | 48 | 29.14 | 29.89 | − .07 | 72.7 | +0.1 | 97 | 31 | 83 | 51 | 4 | 63 | 29 | | ..... | ..... | ..... | 6.91 | +2.9 | 12 | 3,007 | s. | 30 | nw. | 31 | 14 | 9 | 8 | 4.5 | | |
| Madison | 974 | 70 | 78 | 28.91 | 29.93 | − .04 | 71.8 | −0.6 | 95 | 31 | 81 | 55 | 3 | 63 | 31 | 65 | 62 | 76 | 3.10 | −0.9 | 8 | 5,460 | w. | 35 | sw. | 22 | 8 | 16 | 7 | 5.3 | | |
| Wausau | 1,247 | 4 | ..... | 28.60 | 29.91 | ..... | 68.4 | ..... | 97 | 30 | 79 | 42 | 4 | 58 | 31 | | | | | 4.91 | ..... | 12 | ..... | nw. | ..... | ..... | ..... | ..... | 11 | 13 | 7 | 4.8 | | |
| Charles City | 1,015 | 10 | 49 | 28.87 | 29.92 | − .04 | 72.4 | −1.1 | 98 | 30 | 83 | 46 | 3 | 61 | 29 | 66 | 62 | 73 | 5.00 | +1.4 | 10 | 4,051 | nw. | 24 | se. | 5 | 16 | 12 | 3 | 4.3 | | |
| Davenport | 606 | 71 | 79 | 29.28 | 29.93 | − .04 | 75.8 | +0.4 | 98 | 30 | 86 | 52 | 3 | 66 | 27 | 67 | 63 | 69 | 2.72 | −0.8 | 10 | 4,636 | sw. | 27 | s. | 22 | 17 | 10 | 4 | 3.9 | | |
| Des Moines | 861 | 84 | 97 | 29.01 | 29.90 | − .06 | 76.6 | +1.1 | 101 | 30 | 87 | 52 | 3 | 66 | 27 | 67 | 62 | 63 | 1.58 | −2.3 | 8 | 5,009 | n. | 35 | sw. | 31 | 17 | 11 | 3 | 3.3 | | |
| Dubuque | 698 | 81 | 96 | 29.21 | 29.94 | − .03 | 73.8 | −0.9 | 99 | 30 | 83 | 51 | 4 | 64 | 28 | 66 | 62 | 70 | 2.10 | −2.2 | 11 | 4,040 | s. | 20 | nw. | 11 | 12 | 12 | 7 | 4.7 | | |
| Keokuk | 614 | 64 | 78 | 29.28 | 29.94 | − .04 | 76.6 | −0.4 | 100 | 30 | 87 | 55 | 3 | 66 | 25 | 68 | 64 | 67 | 2.65 | −1.4 | 9 | 4,640 | s. | 32 | sw. | 22 | 17 | 14 | 0 | 2.7 | | |
| Cairo | 356 | 87 | 93 | 29.58 | 29.95 | − .05 | 78.0 | −0.6 | 93 | 1 | 86 | 63 | 16 | 70 | 22 | 71 | 68 | 76 | 4.74 | +1.3 | 11 | 4,977 | sw. | 40 | nw. | 26 | 10 | 14 | 7 | 4.9 | | |
| Peoria | 609 | 11 | 45 | 29.30 | 29.96 | − .02 | 75.0 | −0.4 | 98 | 30 | 86 | 49 | 3 | 64 | 29 | 67 | 64 | 74 | 1.92 | −1.0 | 9 | 3,587 | s. | 21 | s. | 1 | 13 | 18 | 0 | 3.9 | | |
| Springfield, Ill | 644 | 10 | 91 | 29.27 | 29.93 | − .05 | 76.7 | +0.2 | 98 | 30 | 87 | 55 | 4 | 66 | 27 | 68 | 64 | 70 | 3.86 | +1.0 | 10 | 4,755 | s. | 26 | e. | 23 | 14 | 14 | 3 | 3.9 | | |
| Hannibal | 534 | 74 | 109 | 29.37 | 29.93 | − .05 | 77.2 | −0.2 | 102 | 30 | 88 | 54 | 4 | 67 | 27 | | | | | 1.71 | −2.0 | 13 | 5,700 | sw. | 40 | s. | 6 | 16 | 14 | 1 | 3.7 | | |
| St. Louis | 567 | 265 | 303 | 29.35 | 29.94 | − .05 | 78.9 | −0.2 | 96 | 13 | 88 | 62 | 4 | 70 | 27 | 69 | 65 | 67 | 3.17 | −0.3 | 10 | 7,777 | sw. | 47 | nw. | 27 | 11 | 18 | 2 | 4.5 | | |
| *Missouri Valley.* | | | | | | | 77.7 | +2.0 | | | | | | | | | | | 60 | 1.85 | −2.0 | | | | | | | | | 2.7 | | |
| Columbia, Mo | 781 | 11 | 84 | 29.12 | 29.93 | −0.05 | 77.6 | +0.2 | 102 | 30 | 89 | 54 | 4 | 66 | 27 | | | | | 0.93 | −2.7 | 7 | 4,722 | s. | 34 | nw. | 6 | 17 | 11 | 3 | 3.5 | | |
| Kansas City | 963 | 161 | 181 | 28.91 | 29.90 | − .07 | 79.9 | +2.3 | 100 | 30 | 90 | 60 | 17 | 70 | 28 | 67 | 61 | 56 | 1.02 | −3.8 | 8 | 7,433 | s. | 35 | ne. | 22 | 21 | 9 | 1 | 2.6 | | |
| St. Joseph | 967 | 11 | 49 | 28.91 | 29.90 | ..... | 79.7 | ..... | 103 | 30 | 91 | 56 | 3 | 68 | 31 | 68 | 62 | 61 | 1.04 | ..... | 9 | 5,136 | s. | 43 | nw. | 12 | 22 | 8 | 1 | 2.2 | | |
| Springfield, Mo | 1,324 | 98 | 104 | 28.59 | 29.96 | − .02 | 76.5 | +0.1 | 94 | 7 | 86 | 59 | 16 | 67 | 25 | 68 | 63 | 68 | 4.15 | −0.6 | 9 | 6,624 | s. | 33 | nw. | 14 | 20 | 8 | 3 | 3.2 | | |
| Iola | 984 | 11 | 50 | 28.90 | 29.92 | − .06 | 80.5 | +2.4 | 103 | 13 | 93 | 57 | 17 | 68 | 37 | ..... | ..... | ..... | 4.22 | +0.3 | 9 | 4,597 | s. | 32 | ne. | 18 | 18 | 13 | 0 | 2.7 | | |
| Topeka | 987 | 85 | 101 | ..... | ..... | ..... | 80.4 | +2.8 | 102 | 30 | 92 | 58 | 16 | 68 | 35 | ..... | ..... | ..... | 0.57 | −4.3 | 7 | 6,685 | s. | 33 | nw. | 15 | 20 | 10 | 1 | 2.4 | | |
| Drexel | 1,299 | 10 | 54 | 28.55 | 29.90 | ..... | 76.2 | ..... | 103 | 29 | 88 | 50 | 3 | 64 | 33 | 67 | 62 | 64 | 0.70 | ..... | 6 | 6,574 | s. | 36 | sw. | 21 | 22 | 8 | 1 | 2.3 | | |
| Lincoln | 1,189 | 11 | 84 | 28.66 | 29.89 | − .06 | 78.4 | +2.0 | 106 | 30 | 91 | 54 | 3 | 66 | 38 | 66 | 60 | 59 | 0.56 | −3.3 | 5 | 6,601 | s. | 38 | w. | 31 | 21 | 8 | 2 | 2.3 | | |
| Omaha | 1,105 | 115 | 122 | 28.76 | 29.90 | − .05 | 79.0 | +2.5 | 104 | 29 | 89 | 58 | 3 | 69 | 26 | 67 | 60 | 57 | 0.78 | −3.6 | 7 | 5,115 | nw. | 31 | n. | 11 | 23 | 7 | 1 | 2.4 | | |
| Valentine | 2,598 | 47 | 54 | 27.26 | 29.91 | − .02 | 75.7 | +2.5 | 103 | 28 | 90 | 48 | 2 | 61 | 39 | 62 | 54 | 53 | 0.84 | −2.6 | 7 | 6,926 | s. | 38 | s. | 6 | 22 | 9 | 0 | 2.7 | | |
| Sioux City | 1,135 | 94 | 164 | 28.72 | 29.90 | − .05 | 76.3 | +2.1 | 103 | 29 | 88 | 45 | 3 | 65 | 32 | 67 | 62 | 62 | 0.85 | −2.8 | 8 | 7,517 | s. | 39 | n. | 11 | 22 | 9 | 0 | 2.1 | | |
| Huron | 1,306 | 59 | 74 | 28.53 | 29.90 | − .04 | 74.0 | +2.5 | 104 | 28 | 87 | 42 | 3 | 61 | 35 | 64 | 58 | 62 | 3.65 | −0.7 | 7 | 6,976 | se. | 44 | sw. | 31 | 22 | 7 | 2 | 2.5 | | |
| Pierre | 1,572 | 70 | 75 | 28.24 | 29.86 | − .07 | 78.2 | +3.0 | 109 | 28 | 92 | 46 | 3 | 64 | 36 | 65 | 57 | 56 | 2.68 | +0.3 | 7 | 6,937 | se. | 70 | w. | 30 | 19 | 8 | 4 | 2.9 | | |
| Yankton | 1,233 | 49 | 57 | 28.60 | 29.89 | − .05 | 75.9 | +1.3 | 103 | 29 | 87 | 47 | 3 | 65 | 31 | ..... | ..... | ..... | 1.96 | +1.6 | 9 | 4,988 | se. | 44 | nw. | 21 | 17 | 13 | 1 | 3.5 | | |

TABLE I.—*Climatological data for Weather Bureau stations, July, 1917*—Continued.

| Districts and stations. | Elevation of instruments. | | | Pressure. | | | Temperature of the air. | | | | | | | | | | | | Mean wet thermometer. | Mean temperature of the dew point. | Mean relative humidity. | Precipitation. | | | Wind. | | | | | | Clear days. | Partly cloudy days. | Cloudy days. | Average cloudiness, tenths. | Total snowfall. | Snow on ground at end of month. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barometer above sealevel. | Thermometer above ground. | Anemometer above ground. | Station, reduced to mean of 24 hours. | Sealevel, reduced to mean of 24 hours. | Departure from normal. | Mean max.+mean min.÷2. | Departure from normal. | Maximum. | Date. | Mean maximum. | Minimum. | Date. | Mean minimum. | Greatest daily range. | | | | | | | Total. | Departure from normal. | Days with 0.01 inch or more. | Total movement. | Prevailing direction. | Maximum velocity. Miles per hour. | Maximum velocity. Direction. | Maximum velocity. Date. | | | | | | |
| | *Ft.* | *Ft.* | *F.* | *In.* | *In.* | *In.* | *°F.* | *°F.* | *F.* | | *°F* | *°F.* | | *°F* | *°F.* | *°F.* | *°F.* | *°F.* | *%* | *In.* | *In.* | | *Miles* | | | | | | | | *0–10* | *In.* | *In.* |
| *Northern Slope.* | | | | | | | 71.7 | +3.6 | | | | | | | | | | | 48 | 0.62 | −0.9 | | | | | | | | | | 3.0 | | |
| Billings | 3,140 | 5 | | | | | 73.6 | | 102 | 23 | 92 | 44 | 1 | 55 | 48 | | | | | 1.00 | | 7 | | sw. | | | | 20 | 11 | 0 | | | |
| Havre | 2,505 | 11 | 44 | 27.28 | 29.85 | −0.06 | 73.7 | +5.6 | 100 | 26 | 89 | 43 | 30 | 58 | 46 | 58 | 48 | 48 | | 0.45 | −1.5 | 6 | 5,019 | sw. | 33 | w. | 29 | 26 | 5 | 0 | 2.0 | | |
| Helena | 4,110 | 87 | 114 | 25.80 | 29.89 | − .04 | 72.2 | +5.6 | 96 | 22 | 87 | 44 | 1 | 57 | 40 | 54 | 40 | 36 | | 0.28 | −0.8 | 5 | 6,490 | sw. | 36 | se. | 8 | 19 | 11 | 1 | 3.0 | | |
| Kalispell | 2,962 | 11 | 34 | 26.90 | 29.88 | − .05 | 67.4 | +3.1 | 95 | 19 | 85 | 38 | 31 | 50 | 43 | 52 | 41 | 48 | | 0.09 | −0.8 | 2 | 3,583 | w. | 20 | w. | 30 | 21 | 8 | 2 | 2.6 | | |
| Miles City | 2,371 | 48 | 55 | 27.41 | 29.88 | − .04 | 78.0 | +5.1 | 106 | 27 | 92 | 53 | 2 | 64 | 46 | 63 | 55 | 50 | | 0.63 | −0.7 | 5 | 4,407 | n. | 24 | n. | 6 | 24 | 7 | 0 | 2.6 | | |
| Rapid City | 3,259 | 50 | 58 | 26.60 | 29.91 | − .02 | 74.6 | +4.4 | 101 | 28 | 88 | 50 | 2 | 61 | 35 | 60 | 49 | 44 | | 0.98 | −1.6 | 4 | 6,122 | n. | 44 | w. | 4 | 17 | 13 | 1 | 3.3 | | |
| Cheyenne | 6,088 | 84 | 101 | 24.12 | 29.95 | + .03 | 67.4 | 0.0 | 88 | 24 | 81 | 41 | 1 | 54 | 36 | 54 | 47 | 56 | | 1.62 | −0.4 | 10 | 7,256 | w. | 43 | sw. | 21 | 10 | 20 | 1 | 4.3 | | |
| Lander | 5,372 | 60 | 68 | 24.71 | 29.91 | − .01 | 71.8 | +3.8 | 96 | 22 | 88 | 42 | 1 | 55 | 41 | 54 | 42 | 41 | | T. | −0.9 | 0 | 3,451 | sw. | 34 | w. | 30 | 12 | 18 | 1 | 4.1 | | |
| Sheridan | 3,790 | 10 | 47 | 26.11 | 29.92 | ..... | 71.2 | ..... | 100 | 23 | 89 | 43 | 1 | 54 | 46 | 57 | 47 | 47 | | 0.17 | ..... | 7 | 3,589 | s. | 32 | ne. | 13 | 17 | 11 | 3 | 3.5 | | |
| Yellowstone Park | 6,200 | 11 | 48 | 23.98 | 29.95 | + .03 | 64.0 | +2.5 | 87 | 9 | 80 | 36 | 1 | 48 | 43 | 50 | 40 | 49 | | 0.41 | −0.8 | 7 | 5,342 | s. | 39 | sw. | 19 | 17 | 14 | 0 | 3.1 | | |
| North Platte | 2,821 | 11 | 51 | 27.07 | 29.93 | .00 | 76.2 | +2.3 | 104 | 28 | 91 | 50 | 16 | 61 | 44 | 65 | 60 | 64 | | 1.13 | −1.6 | 14 | 4,382 | se. | 48 | ne. | 21 | 27 | 3 | 1 | 1.7 | | |
| *Middle Slope.* | | | | | | | 79.3 | +2.6 | | | | | | | | | | | 51 | 1.56 | −1.4 | | | | | | | | | | 3.5 | | |
| Denver | 5,292 | 106 | 113 | 24.81 | 29.94 | +0.03 | 73.6 | +1.8 | 94 | 27 | 86 | 52 | 3 | 61 | 30 | 58 | 50 | 50 | | 0.31 | −1.3 | 5 | 5,401 | s. | 36 | nw. | 10 | 10 | 18 | 3 | 4.5 | | |
| Pueblo | 4,685 | 80 | 86 | 25.34 | 29.91 | .00 | 76.0 | +1.8 | 99 | 5 | 91 | 53 | 4 | 61 | 43 | 58 | 49 | 47 | | 1.32 | −0.6 | 10 | 4,953 | nw. | 33 | nw. | 22 | 11 | 19 | 1 | 4.2 | | |
| Concordia | 1,392 | 50 | 58 | 28.47 | 29.90 | − .05 | 81.1 | +3.0 | 106 | 30 | 94 | 56 | 17 | 68 | 36 | 66 | 57 | 50 | | 0.60 | −3.0 | 8 | 5,843 | s. | 27 | sw. | 29 | 14 | 17 | 0 | 3.6 | | |
| Dodge City | 2,509 | 11 | 51 | 27.37 | 29.90 | − .03 | 80.4 | +2.7 | 103 | 13 | 94 | 57 | 2 | 67 | 38 | 65 | 57 | 52 | | 2.76 | −0.6 | 11 | 7,430 | s. | 36 | n. | 1 | 20 | 10 | 1 | 2.8 | | |
| Wichita | 1,358 | 139 | 158 | 28.50 | 29.88 | − .08 | 82.2 | +3.2 | 103 | 8 | 94 | 62 | 16 | 71 | 31 | 67 | 58 | 51 | | 1.41 | −2.2 | 4 | 9,573 | s. | 42 | s. | 31 | 22 | 8 | 1 | 2.4 | | |
| Altus | 1,410 | 5 | | | | | 85.4 | | 110 | 9 | 99 | 63 | 19 | 72 | 40 | | | | | 1.47 | | 5 | | s. | | | | 21 | 3 | 7 | | | |
| Muskogee | 652 | 4 | | | | | 82.1 | | 107 | 1 | 95 | 61 | 12 | 69 | 37 | | | | | 1.70 | | 9 | | s. | | | | 18 | 5 | 8 | | | |
| Oklahoma | 1,214 | 10 | 47 | 28.67 | 29.91 | − .05 | 82.6 | +2.8 | 105 | 13 | 95 | 63 | 17 | 70 | 36 | 69 | 63 | 58 | | 2.96 | −0.7 | 8 | 9,425 | s. | 44 | w. | 17 | 16 | 13 | 2 | 3.5 | | |
| *Southern Slope.* | | | | | | | 82.7 | +2.2 | | | | | | | | | | | 47 | 1.00 | −1.8 | | | | | | | | | | 2.9 | | |
| Abilene | 1,738 | 10 | 52 | 28.15 | 29.89 | −0.04 | 85.0 | +2.8 | 104 | 10 | 97 | 66 | 18 | 73 | 30 | 68 | 59 | 48 | | 0.90 | −1.5 | 3 | 7,840 | s. | 34 | s. | 31 | 14 | 13 | 4 | 4.1 | | |
| Amarillo | 3,676 | 10 | 49 | 26.28 | 29.91 | − .01 | 79.4 | +3.3 | 100 | 14 | 93 | 58 | 4 | 66 | 33 | 64 | 56 | 53 | | 2.68 | −0.5 | 7 | 8,394 | se. | 32 | s. | 30 | 23 | 8 | 0 | 2.7 | | |
| Del Rio | 944 | 64 | 71 | 28.94 | 29.90 | .00 | 86.0 | +1.3 | 103 | 11 | 96 | 70 | 21 | 76 | 27 | | | | | 0.37 | −1.9 | 3 | 8,634 | e. | 33 | e. | 17 | 23 | 7 | 1 | 2.2 | | |
| Roswell | 3,566 | 75 | 85 | 26.34 | 29.84 | − .04 | 80.4 | +1.5 | 102 | 14 | 94 | 62 | 3 | 67 | 33 | 61 | 49 | 39 | | 0.07 | −3.4 | 3 | 6,286 | s. | 33 | ne. | 19 | 18 | 12 | 1 | 2.6 | | |
| *Southern Plateau.* | | | | | | | 80.8 | +1.8 | | | | | | | | | | | 43 | 1.07 | −0.2 | | | | | | | | | | 4.3 | | |
| El Paso | 3,762 | 110 | 133 | 26.15 | 29.78 | −0.06 | 83.9 | +3.4 | 103 | 14 | 95 | 66 | 28 | 73 | 31 | 63 | 50 | 37 | | 0.41 | −1.7 | 6 | 7,643 | se. | 39 | s. | 4 | 13 | 16 | 2 | 4.2 | | |
| Santa Fe | 7,013 | 57 | 66 | 23.35 | 29.84 | − .04 | 71.5 | +2.8 | 90 | 14 | 84 | 55 | 31 | 59 | 29 | 54 | 44 | 45 | | 0.45 | −2.3 | 9 | 5,463 | e. | 33 | e. | 15 | 1 | 29 | 1 | 5.3 | | |
| Flagstaff | 6,908 | 8 | 57 | 23.46 | 29.86 | + .03 | 66.5 | +1.5 | 88 | 15 | 80 | 46 | 1 | 52 | 42 | 55 | | | | 5.93 | | 14 | | nw. | 39 | sw. | 26 | 4 | 27 | 0 | | | |
| Phoenix | 1,108 | 11 | 81 | 28.65 | 29.76 | − .02 | 90.0 | −0.4 | 111 | 15 | 103 | 71 | 26 | 77 | 35 | 72 | 63 | 46 | | 3.97 | +2.9 | 7 | 4,440 | w. | 45 | e. | 26 | 22 | 8 | 1 | 3.0 | | |
| Yuma | 141 | 9 | 54 | 29.62 | 29.76 | .00 | 92.2 | +1.3 | 113 | 14 | 105 | 74 | 24 | 80 | 34 | 75 | 68 | 52 | | 0.50 | +0.4 | 3 | 4,296 | sw. | 37 | s. | 17 | 9 | 17 | 5 | 4.8 | | |
| Independence | 3,910 | 11 | 42 | ..... | 29.84 | + .01 | 80.5 | +2.0 | 102 | 11 | 97 | 54 | 9 | 64 | 43 | | | 36 | | T. | −0.1 | 0 | | w. | | | | 14 | 15 | 2 | | | |
| Needles | 488 | 4 | ..... | 29.21 | 29.09 | ..... | 94.8 | ..... | 115 | 8 | 110 | 74 | 8 | 80 | 41 | | | | | 0.54 | | 4 | | s. | | | | 12 | 15 | 4 | | | |
| *Middle Plateau.* | | | | | | | 76.6 | +3.8 | | | | | | | | | | | 36 | 0.40 | −0.1 | | | | | | | | | | 2.9 | | |
| Reno | 4,532 | 74 | 81 | 25.49 | 29.89 | +0.02 | 74.0 | +6.5 | 101 | 11 | 92 | 47 | 28 | 56 | 44 | 54 | 40 | 38 | | 0.04 | −0.1 | 1 | 5,262 | w. | 33 | s. | 15 | 25 | 4 | 2 | 1.6 | | |
| Tonopah | 6,090 | 12 | 20 | 24.13 | 29.89 | ..... | 76.8 | ..... | 96 | 12 | 89 | 56 | 29 | 65 | 30 | 56 | 42 | 35 | | 0.31 | 0.0 | 4 | 5,530 | se. | 28 | se. | 14 | 17 | 13 | 1 | 3.1 | | |
| Winnemucca | 4,344 | 18 | 56 | 25.61 | 29.89 | − .01 | 75.9 | +4.3 | 102 | 12 | 94 | 48 | 10 | 58 | 48 | 54 | 38 | 32 | | 0.06 | −0.1 | 3 | 4,319 | sw. | 46 | s. | 15 | 23 | 7 | 1 | 1.9 | | |
| Modena | 5,479 | 10 | 43 | 24.66 | 29.86 | .00 | 74.5 | +4.8 | 97 | 12 | 90 | 46 | 1 | 59 | 47 | 56 | 43 | 41 | | 1.03 | −0.2 | 7 | 7,380 | sw. | 42 | s. | 13 | 14 | 11 | 6 | 4.4 | | |
| Salt Lake City | 4,360 | 163 | 203 | 25.62 | 29.88 | − .02 | 79.0 | +2.8 | 97 | 22 | 90 | 60 | 1 | 68 | 31 | 59 | 46 | 36 | | 0.68 | +0.1 | 4 | 5,184 | nw. | 36 | sw. | 22 | 18 | 10 | 3 | 3.4 | | |
| Grand Junction | 4,602 | 82 | 96 | 25.39 | 29.88 | − .01 | 79.8 | +0.6 | 99 | 14 | 94 | 55 | 1 | 66 | 36 | 58 | 44 | 34 | | 0.28 | −0.2 | 2 | 5,768 | se. | 42 | se. | 24 | 20 | 10 | 1 | 3.0 | | |
| *Northern Plateau.* | | | | | | | 74.7 | +3.8 | | | | | | | | | | | 38 | 0.40 | −0.4 | | | | | | | | | | 2.4 | | |
| Baker | 3,471 | 48 | 53 | 26.45 | 29.96 | +0.01 | 69.4 | +4.4 | 96 | 11 | 86 | 40 | 29 | 53 | 41 | 53 | 42 | 43 | | 0.04 | −0.4 | 1 | 4,481 | nw. | 24 | nw. | 24 | 23 | 8 | 0 | 1.9 | | |
| Boise | 2,739 | 78 | 86 | 27.11 | 29.89 | − .04 | 77.4 | +4.6 | 103 | 26 | 93 | 52 | 29 | 61 | 42 | 58 | 45 | 37 | | T. | −0.2 | 0 | 3,303 | nw. | 21 | se. | 24 | 21 | 10 | 0 | 2.3 | | |
| Lewiston | 757 | 40 | 48 | 29.13 | 29.92 | − .03 | 76.8 | +3.2 | 105 | 16 | 94 | 49 | 29 | 60 | 46 | | | | | 0.07 | −0.4 | 2 | 2,447 | ne. | 25 | w. | 28 | 22 | 8 | 1 | 2.1 | | |
| Pocatello | 4,477 | 60 | 68 | 25.48 | 29.88 | − .04 | 74.4 | +3.2 | 97 | 26 | 90 | 46 | 1 | 59 | 43 | 55 | 41 | 37 | | 0.16 | −0.5 | 3 | 6,139 | se. | 38 | sw. | 22 | 18 | 10 | 3 | 3.5 | | |
| Spokane | 1,929 | 101 | 110 | 27.91 | 29.91 | − .05 | 72.8 | +4.0 | 100 | 16 | 88 | 45 | 29 | 58 | 40 | 55 | 39 | 37 | | T. | −0.7 | 0 | 5,037 | sw. | 27 | w. | 28 | 18 | 11 | 2 | 2.7 | | |
| Walla Walla | 991 | 57 | 65 | 28.86 | 29.91 | − .06 | 77.2 | +3.1 | 106 | 16 | 92 | 50 | 29 | 62 | 41 | 58 | 43 | 34 | | T. | −0.4 | 0 | 3,365 | s. | 19 | w. | 28 | 22 | 9 | 0 | 1.9 | | |
| *North Pacific Coast Region.* | | | | | | | 64.1 | +1.2 | | | | | | | | | | | 68 | 0.20 | −0.5 | | | | | | | | | | 3.2 | | |
| North Head | 211 | 11 | 56 | 29.85 | 30.07 | −0.01 | 54.8 | −2.9 | 62 | 3 | 57 | 47 | 26 | 52 | 9 | 54 | 53 | 93 | | 0.24 | −0.3 | 7 | 14,057 | nw. | 40 | s. | 26 | 9 | 10 | 12 | 5.9 | | |
| North Yakima | 1,071 | 4 | ..... | ..... | ..... | ..... | 74.0 | ..... | 101 | 18 | 91 | 44 | 29 | 57 | 40 | ..... | ..... | ..... | | 0.01 | ..... | 1 | ..... | nw. | ..... | ..... | ..... | 29 | 1 | 1 | ..... | ..... | ..... |
| Port Angeles | 42 | 8 | 48 | 30.07 | 30.10 | ..... | 55.7 | ..... | 77 | 14 | 64 | 41 | 24 | 47 | 30 | ..... | ..... | ..... | | 0.09 | −0.3 | 4 | 5,290 | nw. | 27 | nw. | 28 | 23 | 5 | 3 | 2.7 | | |
| Seattle | 125 | 215 | 250 | 29.93 | 30.06 | + .02 | 63.4 | −0.1 | 82 | 17 | 73 | 49 | 29 | 54 | 27 | 55 | 49 | 65 | | 0.09 | −0.6 | 4 | 5,432 | n. | 26 | s. | 28 | 17 | 10 | 4 | 3.4 | | |
| Tacoma | 213 | 113 | 120 | 29.83 | 30.05 | − .01 | 63.4 | 0.0 | 83 | 18 | 74 | 48 | 23 | 53 | 30 | 56 | 51 | 68 | | 0.12 | −0.5 | 3 | 4,494 | n. | 23 | sw. | 28 | 17 | 11 | 3 | 3.8 | | |
| Tatoosh Island | 109 | 7 | 57 | 29.98 | 30.08 | + .03 | 53.5 | −1.6 | 63 | 13 | 57 | 47 | 23 | 50 | 13 | 52 | 51 | 94 | | 0.90 | −0.9 | 9 | 8,444 | s. | 44 | s. | 26 | 8 | 8 | 15 | 5.9 | | |
| Medford | 1,425 | 4 | ..... | ..... | ..... | ..... | 74.6 | ..... | 107 | 15 | 95 | 44 | 29 | 54 | 51 | ..... | ..... | ..... | | T. | ..... | 0 | ..... | nw. | ..... | ..... | ..... | 26 | 5 | 0 | ..... | ..... | ..... |
| Portland, Oreg | 153 | 68 | 106 | 29.84 | 30.00 | − .05 | 69.0 | +2.7 | 91 | 14 | 81 | 50 | 23 | 57 | 32 | 58 | 51 | 57 | | 0.01 | −0.5 | 1 | 5,461 | nw. | 27 | sw. | 26 | 22 | 7 | 2 | 2.6 | | |
| Roseburg | 510 | 9 | 57 | 29.45 | 29.98 | − .05 | 71.2 | +5.1 | 100 | 15 | 88 | 48 | 29 | 55 | 44 | 58 | 49 | 55 | | 0.01 | −0.3 | 1 | 2,868 | n. | 16 | nw. | 12 | 30 | 1 | 0 | 0.6 | | |
| *Middle Pacific Coast Region.* | | | | | | | 67.8 | +2.3 | | | | | | | | | | | 55 | 0.00 | 0.0 | | | | | | | | | | 2.8 | | |
| Eureka | 62 | 73 | 89 | 29.94 | 30.01 | −0.04 | 54.8 | −0.5 | 67 | 26 | 59 | 48 | 23 | 50 | 15 | 52 | 50 | 86 | | 0.00 | −0.1 | 0 | 4,827 | n. | 25 | sw. | 26 | 6 | 16 | 9 | 5.8 | | |
| Mount Tamalpais | 2,375 | 11 | 18 | 27.50 | 29.92 | − .03 | 74.0 | +3.5 | 94 | 20 | 82 | 44 | 8 | 66 | 23 | 55 | 39 | 32 | | 0.02 | 0.0 | 1 | 11,615 | w. | 64 | nw. | 20 | 29 | 2 | 0 | 0.8 | | |
| Point Reyes Light | 490 | 7 | 18 | 29.38 | 29.89 | ..... | 52.8 | −0.9 | 62 | 22 | 57 | 46 | 3 | 49 | 16 | ..... | ..... | ..... | | T. | ..... | 0 | 14,944 | nw. | 50 | nw. | 27 | 1 | 8 | 22 | 8.1 | | |
| Red Bluff | 332 | 50 | 56 | 29.47 | 29.81 | − .08 | 84.8 | +2.7 | 110 | 12 | 101 | 58 | 27 | 68 | 41 | 61 | 41 | 27 | | 0.00 | 0.0 | 0 | 3,089 | se. | 15 | se. | 7 | 27 | 4 | 0 | 0.8 | | |
| Sacramento | 69 | 106 | 117 | 29.76 | 29.83 | ..... | 78.6 | +6.1 | 107 | 20 | 96 | 52 | 9 | 61 | 45 | 62 | 51 | 49 | | T. | 0.0 | 0 | 5,989 | s. | 20 | s. | 31 | 28 | 3 | 0 | 0.8 | | |
| San Francisco | 155 | 209 | 213 | 29.74 | 29.91 | − .04 | 59.8 | +2.5 | 88 | 21 | 68 | 49 | 3 | 52 | 32 | 54 | 51 | 80 | | T. | 0.0 | 0 | 9,307 | sw. | 37 | sw. | 11 | 21 | 10 | 0 | 2.1 | | |
| San Jose | 141 | 12 | 110 | 29.78 | 29.93 | ..... | 69.9 | +3.0 | 102 | 21 | 86 | 48 | 27 | 54 | 46 | ..... | ..... | ..... | | T. | 0.0 | 0 | 4,375 | nw. | 21 | se. | 8 | 30 | 1 | 0 | 1.5 | | |
| *South Pacific Coast Region.* | | | | | | | 73.4 | +3.5 | | | | | | | | | | | 64 | 0.00 | 0.0 | | | | | | | | | | 2.9 | | |
| Fresno | 327 | 89 | 98 | 29.46 | 29.80 | −0.03 | 86.0 | +4.0 | 109 | 13 | 102 | 60 | 27 | 70 | 38 | 61 | 42 | 27 | | T. | 0.0 | 0 | 6,397 | nw. | 27 | nw. | 20 | 27 | 4 | 0 | 1.2 | | |
| Los Angeles | 338 | 159 | 191 | 29.53 | 29.88 | − .02 | 72.3 | +4.9 | 88 | 1 | 82 | 60 | 9 | 63 | 26 | 64 | 61 | 77 | | T. | 0.0 | 0 | 4,240 | sw. | 17 | sw. | 30 | 19 | 8 | 4 | 3.4 | | |
| San Diego | 87 | 62 | 70 | 29.80 | 29.89 | − .03 | 68.9 | +2.0 | 78 | 2 | 74 | 61 | 7 | 64 | 15 | 64 | 62 | 82 | | T. | 0.0 | 0 | 4,342 | w. | 21 | nw. | 8 | 14 | 13 | 4 | 4.4 | | |
| San Luis Obispo | 201 | 32 | 40 | 29.72 | 29.93 | − .02 | 66.4 | +3.2 | 89 | 10 | 80 | 73 | 1 | 52 | 43 | 57 | 52 | 69 | | 0.01 | 0.0 | 1 | 2,273 | s. | 12 | w. | 26 | 27 | 4 | 0 | 2.5 | | |
| *West Indies.* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| San Juan, P. R | 82 | 8 | 54 | 29.95 | 30.04 | +0.05 | 79.6 | ..... | 90 | 22 | 84 | 71 | 13 | 75 | 17 | 76 | 74 | 79 | | 4.67 | −1.8 | 2 | 213,9 | 54 e. | | 50 e. | | 12 | 8 | 17 | 6 | 5.3 | ..... | ..... |
| *Panama Canal.* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Balboa Heights | 118 | 7 | 97 | 29.74 | 29.86 | ..... | 79.1 | ..... | 89 | 5 | 85 | 71 | 25 | 73 | 17 | 75 | 74 | 92 | | 10.17 | +2.2 | 23 | 3,887 | nw. | 28 | nw. | 8 | 0 | 8 | 23 | 8.0 | ..... | ..... |
| Colon | 36 | 5 | 71 | 29.82 | 29.86 | ..... | 79.0 | ..... | 87 | 21 | 83 | 71 | 22 | 74 | 13 | 76 | 75 | 89 | | 13.58 | −2.6 | 23 | 4,435 | s. | 29 | nw. | 8 | 0 | 8 | 23 | 8.2 | ..... | ..... |
| *Alaska.* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Juneau | 80 | 11 | 49 | ..... | ..... | ..... | 52.7 | ..... | 73 | 22 | 58 | 41 | 9 | 47 | 30 | 51 | 50 | 90 | | 10.49 | ..... | 23 | 2,788 | s. | 13 | se. | 1 | 4 | 2 | 25 | 8.5 | ..... | ..... |

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during July, 1917, at all stations furnished with self-registering gages.*

| Stations. | Date. | Total duration. | | Total amount of precipitation. | Excessive rate. | | Amount before excessive rate began. | Depths of precipitation (in inches) during periods of time indicated. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | From— | To— | | Began— | Ended— | | 5 min. | 10 min. | 15 min. | 20 min. | 25 min. | 30 min. | 35 min. | 40 min. | 45 min. | 50 min. | 60 min. | 80 min | 100 min. | 120 min. |
| Abilene, Tex. | 18 | | | 0.77 | | | | | | | | | | | | | | 0.67 | | | |
| Albany, N. Y. | 15 | | | 0.48 | | | | | | | | | | | | | | 0.45 | | | |
| Alpena, Mich. | 20 | | | 0.43 | | | | | | | | | | | | | | 0.36 | | | |
| Amarillo, Tex. | 10 | 2:40 a. m. | D. N. a. m. | 0.87 | 2:50 a. m. | 3:15 a. m. | 0.01 | 0.12 | 0.31 | 0.50 | 0.62 | 0.67 | | | | | | | | | |
| Anniston, Ala. | 28 | 12:45 p. m. | 1:50 p. m. | 0.86 | 12:59 p. m. | 1:21 p. m. | 0.01 | 0.24 | 0.46 | 0.64 | 0.77 | 0.81 | | | | | | | | | |
| Asheville, N. C. | 31 | | | 0.49 | | | | | | | | | | | | | | 0.49 | | | |
| Atlanta, Ga. | 31 | 12:50 p. m. | 2:05 p. m. | 0.60 | 1:13 p. m. | 1:38 p. m. | 0.01 | 0.05 | 0.18 | 0.37 | 0.50 | 0.55 | | | | | | | | | |
| Atlantic City, N. J. | 10–11 | 10:14 p. m. | D. N. a. m. | 1.51 | 10:36 p. m. | 11:08 p. m. | 0.02 | 0.05 | 0.14 | 0.28 | 0.50 | 0.90 | 1.16 | 1.22 | | | | | | | |
| Augusta, Ga. | 9 | 6:10 p. m. | 8:20 p. m. | 0.75 | 6:50 p. m. | 7:10 p. m. | 0.01 | 0.20 | 0.45 | 0.66 | 0.72 | | | | | | | | | | |
| | 17 | 2:40 p. m. | 3:00 p. m. | 1.05 | 2:32 p. m. | 2:54 p. m. | 0.01 | 0.30 | 0.56 | 0.91 | 1.03 | 1.04 | | | | | | | | | |
| | 20 | 2:35 p. m. | 5:00 p. m. | 1.53 | 3:09 p. m. | 3:47 p. m. | 0.05 | 0.30 | 0.62 | 0.86 | 1.05 | 1.12 | 1.20 | 1.26 | 1.30 | | | | | | |
| Baker Oreg. | 19 | | | 0.04 | | | | | | | | | | | | | | 0.04 | | | |
| Baltimore, Md. | 2–3 | 5:25 p. m. | D. N. a. m. | 1.23 | 5:44 p. m. | 6:02 p. m. | 0.12 | 0.13 | 0.37 | 0.55 | 0.62 | | | | | | | | | | |
| | 10 | 3:54 p. m. | 8:10 p. m. | 1.69 | 4:24 p. m. | 5:06 p. m. | 0.04 | 0.06 | 0.19 | 0.36 | 0.72 | 1.00 | 1.22 | 1.34 | 1.42 | 1.46 | | | | | |
| Bentonville, Ark. | 14 | 4:35 p. m. | 8:20 p. m. | 2.47 | 4:42 p. m. | 5:32 p. m. | 0.01 | 0.15 | 0.55 | 0.88 | 1.15 | 1.20 | 1.24 | 1.35 | 1.40 | 1.45 | 1.61 | | | | |
| | | | | | 5:32 p. m. | 6:05 p. m. | ..... | 1.64 | 1.65 | 1.70 | 1.85 | 1.94 | 2.00 | | | | | | | | |
| Binghamton, N. Y. | 29 | | | 0.68 | | | | | | | | | | | | | | 0.47 | | | |
| Birmingham, Ala. | 22 | 10:08 a. m. | 12:32 p. m. | 0.87 | 10:13 a. m. | 10:25 a. m. | 0.01 | 0.65 | 0.72 | ..... | | | | | | | | | | | |
| Bismarck, N. Dak. | 30 | | | 0.24 | | | | | | | | | | | | | | 0.24 | | | |
| Block Island, R. I. | 19 | 10:32 a. m. | 11:55 a. m. | 1.22 | 10:52 a. m. | 11:08 a. m. | 0.24 | 0.23 | 0.35 | 0.66 | 0.75 | | | | | | | | | | |
| Boise, Idaho. | 26 | | | T. | | | | | | | | | | | | | | T. | | | |
| Boston, Mass. | 27 | 3:18 p. m. | 3:50 p. m. | 0.57 | 3:27 p. m. | 3:42 p. m. | T. | 0.25 | 0.33 | 0.57 | | | | | | | | | | | |
| Buffalo, N. Y. | 9 | 8:45 p. m. | 11:30 p. m. | 0.70 | 8:59 p. m. | 9:09 p. m. | 0.03 | 0.34 | 0.53 | ..... | | | | | | | | | | | |
| | 10 | 3:26 p. m. | 10:55 p. m. | 1.34 | 3:30 p. m. | 3:58 p. m. | 0.01 | 0.13 | 0.44 | 0.69 | 0.77 | 0.96 | 1.02 | | | | | | | | |
| Burlington, Vt. | 30 | | | 0.39 | | | | | | | | | | | | | | 0.38 | | | |
| Cairo, Ill. | 14 | 2:30 p. m. | 4:42 p. m. | 1.23 | 2:46 p. m. | 3:16 p. m. | 0.01 | 0.12 | 0.37 | 0.54 | 0.85 | 1.08 | 1.13 | | | | | | | | |
| | 14 | 7:22 p. m. | 9:35 p. m. | 1.23 | 7:53 p. m. | 8:20 p. m. | 0.01 | 0.27 | 0.63 | 0.94 | 1.07 | 1.13 | 1.16 | | | | | | | | |
| | 16 | 4:50 p. m. | 5:49 p. m. | 0.83 | 5:09 p. m. | 5:22 p. m. | 0.01 | 0.16 | 0.54 | 0.67 | | | | | | | | | | | |
| Canton, N. Y. | 19 | | | 0.81 | | | | | | | | | | | | | | 0.64 | | | |
| Charles City, Iowa. | 20–21 | 9:44 p. m. | 1:50 p. m. | 1.81 | 9:40 a. m. | 9:55 a. m. | 1.05 | 0.19 | 0.40 | 0.51 | | | | | | | | | | | |
| | 31 | 6:15 p. m. | 11:20 p. m. | 1.59 | 7:02 p. m. | 7:27 p. m. | 0.17 | 0.11 | 0.33 | 0.55 | 0.60 | | | | | | | | | | |
| | 2–3 | D. N. p. m. | D. N. a. m. | 1.56 | 12:18 a. m. | 12:48 a. m. | 0.03 | 0.12 | 0.31 | 0.55 | 0.88 | 1.18 | 1.27 | | | | | | | | |
| | 4 | 7:07 p. m. | 8:55 p. m. | 0.63 | 7:21 p. m. | 7:35 p. m. | 0.05 | 0.13 | 0.33 | 0.50 | | | | | | | | | | | |
| Charleston, S. C. | 7 | 12:38 p. m. | 2:10 p. m. | 1.57 | 1:00 p. m. | 1:35 p. m. | 0.03 | 0.37 | 0.72 | 1.00 | 1.16 | 1.26 | 1.32 | 1.38 | | | | | | | |
| | 8 | 7:56 p. m. | 9:50 p. m. | 1.00 | 7:56 p. m. | 8:28 p. m. | 0.00 | 0.22 | 0.51 | 0.71 | 0.82 | 0.89 | 0.94 | 0.97 | | | | | | | |
| | 19 | 8:23 p. m. | 10:30 p. m. | 1.30 | 8:27 p. m. | 9:00 p. m. | 0.01 | 0.07 | 0.23 | 0.39 | 0.49 | 0.70 | 0.89 | 0.99 | | | | | | | |
| | 19–20 | D. N. p. m. | D. N. a. m. | 1.13 | 11:54 p. m. | 12:07 a. m. | 0.02 | 0.28 | 0.53 | 0.58 | | | | | | | | | | | |
| Charlotte, N. C. | 6 | 5:26 p. m. | 6:18 p. m. | 0.84 | 5:26 p. m. | 5:51 p. m. | 0.00 | 0.22 | 0.35 | 0.58 | 0.72 | 0.79 | | | | | | | | | |
| | 9–10 | D. N. p. m. | D. N. a. m. | 1.44 | 10:41 p. m. | 11:14 p. m. | 0.01 | 0.15 | 0.39 | 0.60 | 0.72 | 0.93 | 1.15 | 1.19 | | | | | | | |
| Chattanooga, Tenn. | 2 | 7:35 p. m. | 9:18 p. m. | 0.66 | 8:00 p. m. | 8:23 p. m. | 0.01 | 0.07 | 0.19 | 0.32 | 0.50 | 0.58 | | | | | | | | | |
| Cheyenne, Wyo. | 10 | | | 0.36 | | | | | | | | | | | | | | 0.34 | | | |
| Chicago, Ill. | 26 | 2:12 p. m. | 3:10 p. m. | 0.58 | 2:32 p. m. | 2:47 p. m. | 0.01 | 0.23 | 0.41 | 0.57 | | | | | | | | | | | |
| Cincinnati, Ohio. | 26 | 10:20 a. m. | 11:30 a. m. | 1.05 | 10:32 a. m. | 10:51 a. m. | 0.05 | 0.22 | 0.61 | 0.84 | 0.96 | | | | | | | | | | |
| Cleveland, Ohio. | 14 | 7:24 p. m. | 10:3[illegible] p. m. | 1.80 | 9:38 p. m. | 10:08 p. m. | 0.79 | 0.20 | 0.26 | 0.40 | 0.66 | 0.83 | 0.93 | | | | | | | | |
| Columbia, Mo. | 6 | | | 0.30 | | | | | | | | | | | | | | 0.23 | | | |
| Columbia, S. C. | 4 | 3:00 p. m. | 4:10 p. m. | 0.67 | 3:09 p. m. | 3:36 p. m. | 0.03 | 0.08 | 0.23 | 0.41 | 0.51 | 0.58 | 0.62 | | | | | | | | |
| | 17 | 4:10 p. m. | 7:10 p. m. | 0.78 | 4:14 p. m. | 4:32 p. m. | 0.01 | 0.18 | 0.30 | 0.39 | 0.46 | | | | | | | | | | |
| Columbus, Ohio. | 7 | | | 1.40 | | | | | | | | | | | | | | 0.59 | | | |
| Concord, N. H. | 11 | | | 0.85 | | | | | | | | | | | | | | 0.30 | | | |
| Concordia, Kans. | 31 | | | 0.32 | | | | | | | | | | | | | | 0.25 | | | |
| Corpus Christi, Tex. | 21 | | | 0.95 | | | | | | | | | | | | | | 0.49 | | | |
| Dallas, Tex. | 4 | 8:01 a. m. | 10:39 a. m. | 0.94 | 8:17 a. m. | 8:54 a. m. | 0.03 | 0.14 | 0.27 | 0.36 | 0.45 | 0.57 | 0.73 | 0.78 | 0.81 | | | | | | |
| Davenport, Iowa. | 8 | 3:48 p. m. | 6:25 p. m. | 1.10 | 4:32 p. m. | 5:06 p. m. | 0.08 | 0.13 | 0.20 | 0.22 | 0.31 | 0.60 | 0.81 | 0.87 | | | | | | | |
| Dayton, Ohio. | 13 | 5:20 p. m. | 7:48 p. m. | 0.77 | 6:42 p. m. | 7:26 p. m. | 0.04 | 0.12 | 0.19 | 0.27 | 0.32 | 0.33 | 0.35 | 0.40 | 0.64 | 0.72 | | | | | |
| Del Rio, Tex. | 22 | | | 0.32 | | | | | | | | | | | | | | 0.15 | | | |
| Denver, Colo. | 24 | | | 0.11 | | | | | | | | | | | | | | 0.10 | | | |
| Des Moines, Iowa. | 5 | | | 0.70 | | | | | | | | | | | | | | 0.63 | | | |
| Detroit, Mich. | 7 | | | 1.08 | | | | | | | | | | | | | | 0.35 | | | |
| Devils Lake, N. Dak. | 12 | | | 0.30 | | | | | | | | | | | | | | 0.23 | | | |
| Dodge City, Kans. | 31 | 4:10 p. m. | 5:25 p. m. | 0.95 | 4:16 p. m. | 4:41 p. m. | T. | 0.05 | 0.18 | 0.61 | 0.82 | 0.90 | | | | | | | | | |
| Dubuque, Iowa. | 23 | | | 0.83 | | | | | | | | | | | | | | 0.61 | | | |
| Duluth, Minn. | 31 | | | 1.32 | | | | | | | | | | | | | | 0.78 | | | |
| Eastport, Me. | 12 | | | 0.47 | | | | | | | | | | | | | | 0.33 | | | |
| Elkins, W. Va. | 7 | | | 0.59 | | | | | | | | | | | | | | 0.58 | | | |
| El Paso, Tex. | 20 | | | 0.27 | | | | | | | | | | | | | | 0.27 | | | |
| Erie, Pa. | 9 | 8:11 p. m. | 10:55 p. m. | 1.18 | 8:26 p. m. | 8:46 p. m. | 0.11 | 0.16 | 0.36 | 0.47 | 0.54 | | | | | | | | | | |
| | 17 | 6:10 p. m. | 7:35 p. m. | 0.66 | 6:23 p. m. | 6:43 p. m. | 0.03 | 0.08 | 0.18 | 0.40 | 0.52 | | | | | | | | | | |
| Escanaba, Mich. | 1 | D. N. a. m. | D. N. a. m. | 0.60 | 2:32 a. m. | 2:52 a. m. | 0.01 | 0.17 | 0.32 | 0.47 | 0.53 | | | | | | | | | | |
| Eureka. | † | | | † | | | | | | | | | | | | | | | | | |
| Evansville, Ind. | 18 | | | 0.70 | | | | | | | | | | | | | | 0.64 | | | |
| Flagstaff, Ariz. | 25–26 | | | 1.77 | | | | | | | | | | | | | | * | | | |
| Fort Smith, Ark. | 15 | 7:12 a. m. | 9:10 a. m. | 0.65 | 7:32 a. m. | 7:58 a. m. | 0.01 | 0.08 | 0.18 | 0.27 | 0.35 | 0.47 | 0.53 | | | | | | | | |
| Fort Wayne, Ind. | 6–7 | 9:25 p. m. | D. N. a. m. | 1.70 | 9:28 p. m. | 9:44 p. m. | 0.01 | 0.23 | 0.33 | 0.50 | 0.52 | | | | | | | | | | |
| | 9 | 2:47 p. m. | 3:21 p. m. | 0.87 | 2:55 p. m. | 3:12 p. m. | 0.02 | 0.24 | 0.50 | 0.83 | 0.85 | | | | | | | | | | |
| Fort Worth, Tex. | 19 | | | 1.46 | | | | | | | | | | | | | | 0.59 | | | |
| Fresno, Cal. | 31 | | | T. | | | | | | | | | | | | | | T. | | | |
| Galveston, Tex. | 20 | | | 0.17 | | | | | | | | | | | | | | 0.16 | | | |
| Grand Haven, Mich. | 6 | | | 1.20 | | | | | | | | | | | | | | 0.55 | | | |
| Grand Junction, Colo. | 30 | | | 0.21 | | | | | | | | | | | | | | 0.14 | | | |
| Grand Rapids, Mich. | 6–7 | 5:00 p. m. | D. N. a. m. | 2.07 | 7:57 p. m. | 9:00 p. m. | 0.44 | 0.14 | 0.27 | 0.39 | 0.53 | 0.56 | 0.59 | 0.61 | 0.63 | 0.65 | 0.71 | 0.93 | | | |
| | 16 | 4:27 p. m. | 6:10 a. m. | 1.20 | 5:21 p. m. | 5:42 p. m. | 0.07 | 0.08 | 0.17 | 0.28 | 0.48 | 0.52 | | | | | | | | | |
| | 22 | 3:33 p. m. | 4:25 p. m. | 1.56 | 3:36 p. m. | 4:15 p. m. | 0.01 | 0.28 | 0.67 | 0.82 | 0.87 | 0.99 | 1.05 | 1.42 | 1.53 | | | | | | |
| | 23 | 3:05 p. m. | D. N. p. m. | 0.94 | 3:05 p. m. | 3:30 p. m. | 0.00 | 0.16 | 0.36 | 0.62 | 0.82 | 0.87 | | | | | | | | | |
| Green Bay, Wis. | 15 | | | 0.29 | | | | | | | | | | | | | | 0.29 | | | |
| Hannibal, Mo. | 8 | 4:02 p. m. | 6:12 p. m. | 0.70 | 4:12 p. m. | 4:25 p. m. | 0.01 | 0.22 | 0.55 | 0.64 | | | | | | | | | | | |
| Harrisburg, Pa. | 16 | | | 0.80 | | | | | | | | | | | | | | 0.54 | | | |
| Hartford, Conn. | 2 | 4:15 p. m. | 4:42 p. m. | 0.56 | 4:26 p. m. | 4:37 p. m. | 0.03 | 0.20 | 0.52 | 0.53 | | | | | | | | | | | |
| | 24 | 5:57 p. m. | 7:45 p. m. | 1.41 | 6:02 p. m. | 6:45 p. m. | 0.01 | 0.09 | 0.28 | 0.50 | 0.79 | 1.02 | 1.15 | 1.22 | 1.28 | 1.33 | | | | | |
| Hatteras, N. C. | 7 | 6:20 a. m. | 7:25 a. m. | 0.58 | 6:29 a. m. | 6:57 a. m. | 0.02 | 0.12 | 0.25 | 0.32 | 0.38 | 0.47 | 0.52 | | | | | | | | |
| | 9 | 6:07 p. m. | 8:15 p. m. | 0.95 | 6:26 p. m. | 7:02 p. m. | 0.01 | 0.07 | 0.18 | 0.38 | 0.46 | 0.65 | 0.79 | 0.88 | 0.90 | | | | | | |
| Havre, Mont. | 31 | | | 0.25 | | | | | | | | | | | | | | 0.08 | | | |
| Helena, Mont. | 6 | | | 0.15 | | | | | | | | | | | | | | 0.13 | | | |
| Houghton, Mich. | 8 | | | 0.73 | | | | | | | | | | | | | | 0.72 | | | |
| Houston, Tex. | 2 | 5:07 p. m. | 6:50 p. m. | 0.60 | 5:17 p. m. | 5:39 p. m. | 0.03 | 0.13 | 0.30 | 0.41 | 0.47 | 0.51 | | | | | | | | | |
| | 20 | 2:02 p. m. | 7:00 p. m. | 2.08 | 3:53 p. m. | 4:30 p. m. | 0.54 | 0.19 | 0.43 | 0.71 | 0.91 | 1.12 | 1.28 | 1.35 | 1.40 | | | | | | |
| Huron, S. Dak. | 30–31 | 11:25 p. m. | D. N. a. m. | 2.21 | 11:58 p. m. | 12:50 a. m. | 0.03 | 0.14 | 0.21 | 0.27 | 0.62 | 0.96 | 1.34 | 1.52 | 1.58 | 1.75 | 1.88 | 1.94 | | | |
| | 31 | 2:55 p. m. | 3:30 p. m. | 0.81 | 2:57 p. m. | 3:15 p. m. | 0.01 | 0.22 | 0.46 | 0.74 | 0.78 | | | | | | | | | | |
| Indianapolis, Ind. | 13 | 4:15 p. m. | 5:35 p. m. | 0.56 | 5:05 p. m. | 5:27 p. m. | 0.04 | 0.12 | 0.24 | 0.34 | 0.49 | 0.51 | | | | | | | | | |
| | 16 | 9:13 a. m. | 12:53 p. m. | 1.48 | 9:32 a. m. | 10:45 a. m. | 0.01 | 0.27 | 0.44 | 0.51 | 0.55 | 0.58 | 0.60 | 0.63 | 0.71 | 0.78 | 0.81 | 0.84 | 1.16 | | |
| | 26 | 7:02 a. m. | 9:40 a. m. | 0.75 | 7:07 a. m. | 7:20 a. m. | 0.01 | 0.35 | 0.59 | 0.66 | | | | | | | | | | | |

*Self-register not in use. †Record partly estimated. ‡No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during July, 1917, at all stations furnished with self-registering gages*—Continued.

| Stations. | Date. | Total duration. | | Total amount of precipitation. | Excessive rate. | | Amount before excessive rate began. | Depths of precipitation (in inches) during periods of time indicated. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | From— | To— | | Began— | Ended— | | 5 min. | 10 min. | 15 min. | 20 mn. | 25 min. | 30 min. | 35 min. | 40 min. | 45 min. | 50 min. | 60 min. | 80 min. | 100 min. | 120 min. |
| Iola, Kans. | 18 | 3:10 p. m. | 5:30 p. m. | 3.15 | 3:20 p. m. | 4:24 p. m. | 0.02 | 0.17 | 0.38 | 0.56 | 0.83 | 1.06 | 1.41 | 1.70 | 2.10 | 2.38 | 2.65 | 2.92 | 3.02 | ..... | ..... |
| Jacksonville, Fla. | 1 | 8:55 a. m. | 10:05 a. m. | 0.74 | 9:06 a. m. | 9:44 a. m. | 0.02 | 0.08 | 0.13 | 0.24 | 0.38 | 0.50 | 0.58 | 0.64 | 0.70 | ..... | ..... | ..... | ..... | ..... | ..... |
| | 4 | 11:15 a. m. | 12:10 p. m. | 1.35 | 11:17 a. m. | 11:47 a. m. | 0.01 | 0.11 | 0.53 | 0.64 | 0.99 | 1.19 | 1.29 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 27 | 4:03 p. m. | 6:10 p. m. | 3.01 | 4:17 p. m. | 5:02 p. m. | 0.10 | 0.11 | 0.31 | 0.63 | 1.10 | 1.77 | 2.26 | 2.57 | 2.71 | 2.80 | ..... | ..... | ..... | ..... | ..... |
| | 30 | 1:15 p. m. | 2:13 p. m. | 1.39 | 1:18 p. m. | 1:50 p. m. | 0.01 | 0.27 | 0.60 | 0.91 | 1.10 | 1.16 | 1.30 | 1.36 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Kalispell, Mont. | 30 | ..... | ..... | 0.07 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.07 | ..... | ..... | ..... |
| Kansas City, Mo. | 6 | ..... | ..... | 0.29 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.27 | ..... | ..... | ..... |
| Keokuk, Iowa. | 22 | 1:05 p. m. | 3:25 p. m. | 0.78 | 1:17 p. m. | 1:32 p. m. | 0.03 | 0.21 | 0.50 | 0.63 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 23 | 5:35 a. m. | 7:12 a. m. | 0.87 | 5:38 a. m. | 5:58 a. m. | 0.01 | 0.20 | 0.40 | 0.58 | 0.70 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Key West, Fla. | 5 | ..... | ..... | 0.29 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.27 | ..... | ..... | ..... |
| Knoxville, Tenn. | 12 | 1:00 p. m. | 6:30 p. m. | 1.46 | 2:52 p. m. | 3:06 p. m. | 0.38 | 0.21 | 0.42 | 0.60 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 14–15 | 6:05 p. m. | D. N. a. m. | 2.14 | 6:39 p. m. | 7:16 p. m. | 0.27 | 0.29 | 0.34 | 0.34 | 0.35 | 0.37 | 0.53 | 0.62 | 0.67 | ..... | ..... | ..... | ..... | ..... | ..... |
| | | | | | 9:01 p. m. | 9:20 p. m. | 1.11 | 0.16 | 0.31 | 0.54 | 0.86 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 16 | 8:02 a. m. | 12:30 p. m. | 4.01 | 9:03 a. m. | 11:05 a. m. | 0.15 | 0.22 | 0.29 | 0.39 | 0.56 | 0.81 | 0.94 | 1.05 | 1.18 | 1.29 | 1.35 | 1.62 | 2.38 | 2.86 | 3.30 |
| | 14 | 4:54 p. m. | 6:05 p. m. | 0.84 | 5:02 p. m. | 5:19 p. m. | 0.02 | 0.23 | 0.57 | 0.74 | 0.77 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| La Crosse, Wis. | 21–22 | 9:02 p. m. | .a.m. | 3.67 | 10:09 p. m. | 10:59 p. m. | 0.14 | 0.12 | 0.16 | 0.18 | 0.23 | 0.27 | 0.29 | 0.38 | 0.49 | 0.53 | 0.69 | ..... | ..... | ..... | ..... |
| | | | | | 10:59 p. m. | 11:49 p. m. | ..... | 0.84 | 0.93 | 1.00 | 1.10 | 1.31 | 1.53 | 1.77 | 1.90 | 1.94 | 1.97 | ..... | ..... | ..... | ..... |
| | | | | | 11:49 p. m. | 12:30 a. m. | ..... | 2.00 | 2.08 | 2.14 | 2.20 | 2.23 | 2.25 | 2.31 | 2.52 | 2.56 | ..... | ..... | ..... | ..... | ..... |
| Lander, Wyo. | 10 | ..... | ..... | T. | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | T. | ..... | ..... | ..... |
| Lansing, Mich. | 1 | ..... | ..... | 1.28 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.79 | ..... | ..... | ..... |
| Lewiston, Idaho. | 8 | ..... | ..... | 0.03 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.03 | ..... | ..... | ..... |
| Lexington, Ky. | 19 | 11:55 a. m. | 12:40 p. m. | 1.07 | 12:20 p. m. | 12:39 p. m. | 0.05 | 0.28 | 0.57 | 0.84 | 1.02 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Lincoln, Nebr. | 4 | ..... | ..... | 0.26 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | * | ..... | ..... | ..... |
| Little Rock, Ark. | 6 | 7:14 p. m. | 8:45 p. m. | 0.97 | 8:12 p. m. | 8:29 p. m. | 0.01 | 0.07 | 0.39 | 0.80 | 0.94 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 23 | 3:15 p. m. | 7:20 p. m. | 1.20 | 5:14 p. m. | 6:02 p. m. | 0.06 | 0.14 | 0.17 | 0.19 | 0.21 | 0.29 | 0.51 | 0.78 | 0.93 | 1.05 | 1.09 | ..... | ..... | ..... | ..... |
| Los Angeles, Cal. | 22 | ..... | ..... | T. | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | T. | ..... | ..... | ..... |
| Louisville, Ky. | 1-2 | ..... | ..... | 0.78 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.34 | ..... | ..... | ..... |
| Ludington, Mich. | 16 | ..... | ..... | 0.21 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.18 | ..... | ..... | ..... |
| Lynchburg, Va. | 24 | 5:00 p. m. | 6:00 p. m. | 1.00 | 5:68 p. m. | 5:29 p. m. | 0.01 | 0.10 | 0.37 | 0.68 | 0.80 | 0.81 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Macon, Ga. | 6 | 10:48 a. m. | 11:45 a. m. | 0.83 | 10:57 a. m. | 11:26 a. m. | 0.03 | 0.08 | 0.37 | 0.57 | 0.66 | 0.73 | 0.78 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 25 | 7:00 p. m. | 8:40 p. m. | 0.61 | 7:07 p. m. | 7:36 p. m. | 0.01 | 0.09 | 0.27 | 0.38 | 0.45 | 0.53 | 0.57 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Madison, Wis. | 22 | 2:10 a. m. | 4:00 a. m. | 1.36 | 3:18 a. m. | 3:45 a. m. | 0.16 | 0.13 | 0.33 | 0.58 | 0.94 | 1.15 | 1.19 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Marquette, Mich. | 31 | ..... | ..... | 0.65 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.44 | ..... | ..... | ..... |
| Memphis, Tenn. | 15 | D. N. a. m. | 10:50 a. m. | 0.94 | 6:44 a. m. | 7:14 a. m. | 0.21 | 0.09 | 0.22 | 0.24 | 0.35 | 0.48 | 0.56 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 19 | 11:22 a. m. | 2:20 p. m. | 1.62 | 11:46 a. m. | 1:37 p. m. | 0.12 | 0.08 | 0.24 | 0.44 | 0.70 | 1.00 | 1.07 | 1.10 | 1.13 | 1.24 | 1.34 | 1.40 | ..... | ..... | ..... |
| | 23 | 8:45 a. m. | 10:40 a. m. | 0.79 | 9:31 a. m. | 9:50 a. m. | 0.15 | 0.06 | 0.23 | 0.44 | 0.59 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Meridian, Miss. | 21 | 7:44 a. m. | 10:05 a. m. | 1.43 | 8:39 a. m. | 9:33 a. m. | 0.18 | 0.06 | 0.10 | 0.16 | 0.18 | 0.25 | 0.31 | 0.37 | 0.48 | 0.78 | 1.09 | 1.21 | ..... | ..... | ..... |
| Miami, Fla. | 10 | 2:35 p. m. | 4:10 p. m. | 0.73 | 2:58 p. m. | 3:29 p. m. | 0.08 | 0.07 | 0.20 | 0.37 | 0.42 | 0.50 | 0.56 | 0.59 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Milwaukee, Wis. | 22 | ..... | ..... | 0.29 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.22 | ..... | ..... | ..... |
| Minneapolis, Minn. | 5–6 | 10:00 p. m. | D. N. a. m. | 0.77 | 10:12 p. m. | 10:27 p. m. | 0.04 | 0.21 | 0.45 | 0.54 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 22 | 2:30 p. m. | 3:20 p. m. | 0.72 | 2:37 p. m. | 3:03 p. m. | 0.01 | 0.16 | 0.42 | 0.51 | 0.61 | 0.68 | 0.69 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Mobile, Ala. | 2 | 11:01 a. m. | 12:05 p. m. | 0.88 | 11:08 a. m. | 11:29 a. m. | 0.01 | 0.09 | 0.42 | 0.65 | 0.70 | 0.87 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 12 | 10:09 a. m. | 4:10 p. m. | 2.71 | 10:30 a. m. | 11:28 a. m. | 0.08 | 0.07 | 0.40 | 0.59 | 0.85 | 1.16 | 1.43 | 1.63 | 1.76 | 1.99 | 2.23 | 2.45 | ..... | ..... | ..... |
| | 19 | 5:10 p. m. | 6:56 p. m. | 1.62 | 5:52 p. m. | 6:14 p. m. | 0.01 | 0.60 | 1.33 | 1.48 | 1.56 | 1.59 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Modena, Utah. | 29 | ..... | ..... | 0.32 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.15 | ..... | ..... | ..... |
| Montgomery, Ala. | 17 | 9:06 a. m. | 10:30 a. m. | 0.77 | 9:22 a. m. | 9:37 a. m. | 0.01 | 0.25 | 0.55 | 0.68 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 20 | 3:03 p. m. | 5:25 p. m. | 0.71 | 3:07 p. m. | 3:26 p. m. | 0.01 | 0.29 | 0.36 | 0.40 | 0.50 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 22 | 2:10 p. m. | 3:32 p. m. | 0.73 | 2:12 p. m. | 2:30 p. m. | 0.01 | 0.26 | 0.49 | 0.59 | 0.70 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Moorhead, Minn. | 21 | ..... | ..... | 0.18 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.18 | ..... | ..... | ..... |
| Mount Tamalpais, Cal. | 8 | ..... | ..... | 0.02 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | T. | ..... | ..... | ..... |
| Nantucket, Mass. | 13 | ..... | ..... | 0.76 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.47 | ..... | ..... | ..... |
| Nashville, Tenn. | 23 | ..... | ..... | 0.56 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.53 | ..... | ..... | ..... |
| New Haven, Conn. | 24 | 7:13 p. m. | 8:30 p. m. | 0.68 | 7:22 p. m. | 7:51 p. m. | 0.01 | 0.20 | 0.32 | 0.37 | 0.41 | 0.51 | 0.58 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| New Orleans, La. | 3 | 3:41 p. m. | 7:30 p. m. | 0.86 | 3:48 p. m. | 4:15 p. m. | 0.01 | 0.08 | 0.26 | 0.45 | 0.64 | 0.75 | 0.80 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 6 | 2:15 p. m. | 3:20 p. m. | 1.41 | 2:21 p. m. | 3:11 p. m. | 0.02 | 0.20 | 0.34 | 0.43 | 0.51 | 0.64 | 0.82 | 0.95 | 1.04 | 1.31 | 1.36 | ..... | ..... | ..... | ..... |
| | 7 | 5:00 p. m. | 9:50 p. m. | 2.02 | 5:00 p. m. | 5:51 p. m. | 0.01 | 0.13 | 0.44 | 1.01 | 1.24 | 1.42 | 1.52 | 1.61 | 1.64 | 1.70 | 1.79 | 1.84 | ..... | ..... | ..... |
| | 18 | 11:55 a. m. | 6:35 p. m. | 1.28 | 12:15 p. m. | 12:41 p. m. | 0.02 | 0.31 | 0.62 | 0.85 | 1.03 | 1.11 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 28 | 4:40 p. m. | 5:25 p. m. | 0.82 | 4:52 p. m. | 5:08 p. m. | 0.02 | 0.20 | 0.60 | 0.74 | 0.78 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| New York, N. Y. | 12 | 9:00 p. m. | 10:15 p. m. | 1.05 | 9:32 p. m. | 9:57 p. m. | 0.05 | 0.21 | 0.54 | 0.76 | 0.90 | 0.99 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 22 | 3:50 p. m. | 4:50 p. m. | 1.65 | 3:55 p. m. | 4:25 p. m. | T. | 0.19 | 0.39 | 0.84 | 1.33 | 1.51 | 1.60 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Norfolk, Va. | 10 | 1:49 p. m. | 2:31 p. m. | 0.96 | 1:51 p. m. | 2:18 p. m. | 0.01 | 0.09 | 0.13 | 0.27 | 0.62 | 0.90 | 0.95 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 24 | D. N. a. m. | D. N. a. m. | 1.90 | 3:47 a. m. | 4:25 a. m. | 0.92 | 0.26 | 0.44 | 0.52 | 0.57 | 0.61 | 0.69 | 0.82 | 0.91 | ..... | ..... | ..... | ..... | ..... | ..... |
| | 26 | D. N. a. m. | D. N. a. m. | 1.18 | 3:53 a. m. | 4:14 a. m. | 0.01 | 0.21 | 0.33 | 0.47 | 0.75 | 0.78 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Northfield, Vt. | 22 | ..... | ..... | 1.06 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.90 | ..... | ..... | ..... |
| North Head, Wash. | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| North Platte, Nebr. | 29 | ..... | ..... | 0.20 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.17 | ..... | ..... | ..... |
| Oklahoma, Okla. | 18 | ..... | ..... | 1.22 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1.22 | ..... | ..... | ..... |
| Omaha, Nebr. | 31 | ..... | ..... | 0.34 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.30 | ..... | ..... | ..... |
| Oswego, N. Y. | 13 | ..... | ..... | 0.29 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.20 | ..... | ..... | ..... |
| Palestine, Tex. | 16 | 5:40 a. m. | 9:40 a. m. | 1.27 | 5:46 a. m. | 6:15 a. m. | T. | 0.19 | 0.38 | 0.53 | 0.62 | 0.68 | 0.75 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 19 | 4:35 p. m. | 5:40 p. m. | 0.79 | 4:57 p. m. | 5:15 p. m. | 0.05 | 0.19 | 0.48 | 0.66 | 0.72 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 19–20 | 11:05 p. m. | 9:20 a. m. | 5.38 | 3:27 a. m. | 4:17 a. m. | 0.91 | 0.10 | 0.30 | 0.63 | 1.07 | 1.40 | 1.72 | 1.82 | 1.92 | 2.02 | 2.06 | ..... | ..... | ..... | ..... |
| | | | | | 4:17 a. m. | 5:07 a. m. | ..... | 2.09 | 2.11 | 2.13 | 2.17 | 2.19 | 2.24 | 2.31 | 2.38 | 2.53 | 2.69 | ..... | ..... | ..... | ..... |
| | | | | | 5:07 a. m. | 5:57 a. m. | ..... | 2.98 | 3.22 | 3.32 | 3.37 | 3.43 | 3.44 | 3.46 | 3.48 | 3.50 | 3.51 | ..... | ..... | ..... | ..... |
| | | | | | 5:57 a. m. | 6:21 a. m. | ..... | 3.54 | 3.69 | 3.81 | 3.90 | 3.97 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Parkersburg, W. Va. | 7 | 1:28 p. m. | 2:50 p. m. | 0.95 | 1:28 p. m. | 1:58 p. m. | 0.00 | 0.13 | 0.47 | 0.59 | 0.69 | 0.80 | 0.91 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 20 | 9:02 p. m. | 9:44 p. m. | 1.27 | 9:02 p. m. | 9:40 p. m. | 0.00 | 0.13 | 0.26 | 0.43 | 0.62 | 0.79 | 1.06 | 1.23 | 1.27 | ..... | ..... | ..... | ..... | ..... | ..... |
| Pensacola, Fla. | 12–13 | ..... | ..... | 1.28 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.42 | ..... | ..... | ..... |
| Peoria, Ill. | 12–13 | ..... | ..... | 0.93 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.58 | ..... | ..... | ..... |
| Philadelphia, Pa. | 10–11 | 3:20 p. m. | 4:20 p. m. | 2.63 | 4:49 p. m. | 6:06 p. m. | 0.17 | 0.13 | 0.24 | 0.32 | 0.36 | 0.38 | 0.40 | 0.46 | 0.61 | 0.68 | 0.74 | 0.87 | 1.12 | ..... | ..... |
| Phoenix, Ariz. | 26 | 8:13 p. m. | 10:50 p. m. | 1.38 | 8:20 p. m. | 9:09 p. m. | 0.01 | 0.14 | 0.30 | 0.48 | 0.64 | 0.74 | 0.88 | 0.95 | 1.03 | 1.17 | 1.28 | ..... | ..... | ..... | ..... |
| | 29 | 2:50 a. m. | 9:50 a. m. | 1.60 | 3:00 a. m. | 4:10 a. m. | 0.01 | * | * | * | * | * | * | * | * | * | * | †1.02 | ..... | ..... | ..... |
| Pierre, S. Dak. | 30 | 5:10 p. m. | 9:50 p. m. | 2.30 | 7:46 p. m. | 9:26 p. m. | 0.01 | 0.36 | 0.59 | 0.77 | 0.90 | 1.06 | 1.19 | 1.20 | 1.20 | 1.20 | 1.21 | 1.39 | 1.91 | 2.25 | ..... |
| Pittsburgh, Pa. | 2 | ..... | ..... | 0.52 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.44 | ..... | ..... | ..... |
| Pocatello, Idaho. | 23 | ..... | ..... | 0.06 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.06 | ..... | ..... | ..... |
| Point Reyes Light, Cal. | 16 | ..... | ..... | T. | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | T. | ..... | ..... | ..... |
| Port Angeles, Wash. | 3 | ..... | ..... | 0.04 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.02 | ..... | ..... | ..... |
| Port Arthur, Tex. | 4 | 11:35 a. m. | 12:25 p. m. | 1.00 | 11:59 p. m. | 12:16 p. m. | 0.01 | 0.16 | 0.57 | 0.96 | 0.99 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 19 | 11:44 a. m. | 3:05 p. m. | 1.42 | 12:57 p. m. | 1:22 p. m. | 0.36 | 0.06 | 0.27 | 0.50 | 0.74 | 0.98 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 20 | 2:30 p. m. | 6:40 p. m. | 1.42 | 3:07 p. m. | 4:03 p. m. | 0.04 | 0.12 | 0.27 | 0.39 | 0.48 | 0.53 | 0.63 | 0.67 | 0.70 | 0.85 | 0.92 | 1.01 | ..... | ..... | ..... |
| Port Huron, Mich. | 7 | 3:38 p. m. | 5:40 p. m. | 1.27 | 3:41 p. m. | 4:41 p. m. | 0.01 | 0.15 | 0.34 | 0.39 | 0.43 | 0.43 | 0.43 | 0.54 | 0.80 | 0.85 | 0.85 | 1.02 | ..... | ..... | ..... |
| Portland, Me. | 24 | ..... | ..... | 0.58 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.54 | ..... | ..... | ..... |
| Portland, Oreg. | 15 | ..... | ..... | 0.01 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.01 | ..... | ..... | ..... |
| Providence, R. I. | 14 | ..... | ..... | 0.30 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.28 | ..... | ..... | ..... |
| Pueblo, Colo. | 8 | ..... | ..... | 0.47 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0.37 | ..... | ..... | ..... |
| Raleigh, N. C. | 3 | 6:32 p. m. | 7:05 p. m. | 0.09 | 6:35 p. m. | 6:53 p. m. | 0.01 | 0.25 | 0.38 | 0.49 | 0.66 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 12 | 5:50 p. m. | 10:15 p. m. | 1.53 | 6:14 p. m. | 7:43 p. m. | 0.01 | 0.18 | 0.23 | 0.25 | 0.28 | 0.30 | 0.35 | 0.49 | 0.64 | 0.73 | 0.82 | 0.92 | 1.21 | 1.46 | ..... |
| | 17 | 5:16 p. m. | 10:30 p. m. | 1.74 | 6:15 p. m. | 6:29 p. m. | 0.02 | 0.25 | 0.58 | 0.73 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 20 | 3:55 p. m. | D. N. p. m. | 1.11 | 4:15 p. m. | 4:36 p. m. | 0.05 | 0.13 | 0.29 | 0.41 | 0.53 | 0.56 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Rapid City, S. Dak. | 3 | ..... | ..... | 0.43 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 0:43 | ..... | ..... | ..... |

* Self-register not working. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during July, 1917, at all stations furnished with self-registering gages*—Continued.

| Stations. | Date. | Total duration. | | Total amount of precipitation. | Excessive rate. | | Amount before excessive rate began. | Depths of precipitation (in inches) during periods of time indicated. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | From— | To— | | Began— | Ended— | | 5 min. | 10 min. | 15 min. | 20 min. | 25 min. | 30 min. | 35 min. | 40 min. | 45 min. | 50 min. | 60 min. | 80 min. | 100 min. | 120 min. |
| Reading, Pa. | 14 | 4:45 p. m. | 7:42 p. m. | 1.07 | 4:55 p. m. | 5:24 p. m. | 0.01 | 0.13 | 0.14 | 0.19 | 0.26 | 0.47 | 0.72 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Red Bluff, Cal. | ‡ | | | ‡ | | | | | | | | | | | | | | | | | |
| Reno, Nev. | 15 | | | 0.04 | | | | | | | | | | | | | | 0.03 | | | |
| Richmond, Va. | | | | | | | | | | | | | | | | | | | | | |
| Rochester, N. Y. | 11 | 3:31 p. m. | 6:30 p. m. | 1.32 | 3:36 p. m. | 3:56 p. m. | 0.01 | 0.14 | 0.43 | 0.59 | 0.65 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Roseburg, Oreg. | 28 | | | 0.01 | | | | | | | | | | | | | | 0.01 | | | |
| Roswell, N. Mex. | 19–20 | | | 0.06 | | | | | | | | | | | | | | 0.04 | | | |
| Sacramento, Cal. | 14 | | | T. | | | | | | | | | | | | | | T. | | | |
| Saginaw, Mich. | 6 | | | 0.64 | | | | | | | | | | | | | | 0.59 | | | |
| St. Joseph, Mo. | 6 | 12:07 a. m. | D. N. a. m. | 0.62 | 12:18 a. m. | 12:37 a. m. | 0.01 | 0.21 | 0.36 | 0.45 | 0.54 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| St. Louis, Mo. | 27 | 1:30 a. m. | D. N. a. m. | 0.72 | 2.00 a. m. | 2:22 a. m. | 0.05 | 0.19 | 0.39 | 0.50 | 0.61 | 0.65 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 28 | 12:48 p. m. | 1:44 p. m. | 1.29 | 1:09 p. m. | 1:32 p. m. | 0.01 | 0.42 | 0.77 | 0.99 | 1.20 | 1.28 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| St. Paul, Minn. | 4 | 9:55 p. m. | 11:45 p. m. | 1.05 | 10:34 p. m. | 11:04 p. m. | 0.09 | 0.11 | 0.17 | 0.24 | 0.36 | 0.45 | 0.62 | 0.82 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 5 | 10:15 p. m. | 12:45 a. m. | 0.73 | 10:46 p. m. | 11:11 p. m. | 0.03 | 0.15 | 0.27 | 0.38 | 0.50 | 0.56 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Salt Lake City, Utah. | 28 | | | 0.38 | | | | | | | | | | | | | | 0.25 | | | |
| San Antonio, Tex. | 20–21 | 6:40 p. m. | 12:15 a. m. | 1.20 | 6:53 p. m. | 7:42 p. m. | 0.02 | 0.12 | 0.29 | 0.43 | 0.46 | 0.48 | 0.50 | 0.55 | 0.63 | 0.71 | 0.78 | ..... | ..... | ..... | ..... |
| San Diego, Cal. | 17 | | | T. | | | | | | | | | | | | | | T. | | | |
| Sand Key, Fla. | 25 | | | 0.45 | | | | | | | | | | | | | | 0.44 | | | |
| Sandusky, Ohio. | 16 | | | 0.12 | | | | | | | | | | | | | | 0.12 | | | |
| Sandy Hook, N. J. | 3 | 10:00 a. m. | 3:25 p. m. | 2.12 | 12:48 p. m. | 2:01 p. m. | 0.33 | 0.17 | 0.37 | 0.59 | 0.72 | 0.82 | 0.90 | 0.96 | 1.05 | 1.14 | 1.19 | 1.24 | 1.45 | ..... | ..... |
| | 14 | 6:37 p. m. | 8:12 p. m. | 0.72 | 7:13 p. m. | 7:31 p. m. | 0.05 | 0.14 | 0.26 | 0.42 | 0.55 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| San Francisco, Cal. | 31 | | | T. | | | | | | | | | | | | | | T. | | | |
| San Jose, Cal. | 31 | | | T. | | | | | | | | | | | | | | T. | | | |
| San Luis Obispo, Cal. | 31 | | | 0.01 | | | | | | | | | | | | | | 0.01 | | | |
| Santa Fe, N. Mex. | 21 | | | 0.13 | | | | | | | | | | | | | | 0.13 | | | |
| Sault Ste. Marie, Mich. | 1 | | | 0.11 | | | | | | | | | | | | | | 0.47 | | | |
| Savannah, Ga. | 2 | D. N. a. m. | 10:25 a. m. | 1.13 | 4:22 a. m. | 4:47 a. m. | 0.05 | 0.15 | 0.25 | 0.41 | 0.53 | 0.58 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 4 | 12:22 p. m. | 1:15 p. m. | 0.64 | 12:34 p. m. | 12:49 p. m. | 0.01 | 0.10 | 0.29 | 0.62 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 6 | 2:23 p. m. | 5:10 p. m. | 0.97 | 2:33 p. m. | 2:59 p. m. | 0.03 | 0.08 | 0.18 | 0.37 | 0.49 | 0.56 | 0.60 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 7 | 3:17 p. m. | 5:20 p. m. | 1.11 | 3:39 p. m. | 4:03 p. m. | 0.04 | 0.27 | 0.57 | 0.78 | 0.91 | 0.95 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 22 | 2:18 p. m. | 3:40 p. m. | 0.76 | 2:36 p. m. | 2:59 p. m. | 0.01 | 0.13 | 0.31 | 0.40 | 0.52 | 0.57 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 24 | 2:53 p. m. | 3:30 p. m. | 0.57 | 2:54 p. m. | 3:18 p. m. | 0.01 | 0.10 | 0.28 | 0.33 | 0.43 | 0.55 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Scranton, Pa. | 20 | | | 0.34 | | | | | | | | | | | | | | 0.32 | | | |
| Seattle, Wash. | 3 | | | 0.03 | | | | | | | | | | | | | | 0.02 | | | |
| Sheridan, Wyo. | 27 | | | 0.08 | | | | | | | | | | | | | | 0.08 | | | |
| Shreveport, La. | 15–16 | 11:50 p. m. | 8:45 a. m. | 2.70 | 4:05 a. m. | 4:50 a. m. | 0.87 | 0.05 | 0.25 | 0.57 | 0.79 | 0.87 | 0.93 | 1.05 | 1.12 | 1.19 | ..... | ..... | ..... | ..... | ..... |
| | 20 | 2:25 a. m. | 11:25 a. m. | 4.94 | 2:57 a. m. | 3:51 a. m. | 0.14 | 0.09 | 0.19 | 0.29 | 0.42 | 0.65 | 0.87 | 0.98 | 1.06 | 1.14 | 1.19 | 1.28 | ..... | ..... | ..... |
| | | | | | 5:15 a. m. | 7:07 a. m. | 1.88 | 0.15 | 0.22 | 0.27 | 0.29 | 0.33 | 0.38 | 0.40 | 0.45 | 0.55 | 0.75 | 0.95 | 1.57 | 2.45 | 2.64 |
| | 24 | 12:50 a. m. | 6:25 a. m. | 0.90 | 2:25 a. m. | 3:12 a. m. | 0.11 | 0.16 | 0.26 | 0.36 | 0.42 | 0.45 | 0.48 | 0.49 | 0.56 | 0.70 | 0.78 | ..... | ..... | ..... | ..... |
| Sioux City, Iowa. | 15 | | | 0.22 | | | | | | | | | | | | | | 0.22 | | | |
| Spokane, Wash. | 4 | | | T. | | | | | | | | | | | | | | T. | | | |
| Springfield, Ill. | 23 | 1:20 p. m. | 4:15 p. m. | 2.58 | 1:29 p. m. | 2:14 p. m. | 0.01 | 0.43 | 1.02 | 1.41 | 1.67 | 1.92 | 2.08 | 2.30 | 2.41 | 2.52 | ..... | ..... | ..... | ..... | ..... |
| Springfield, Mo. | 14 | 3:27 p. m. | 4:30 p. m. | 0.73 | 3:44 p. m. | 4:00 p. m. | 0.01 | 0.25 | 0.47 | 0.67 | 0.72 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 18–19 | 8:40 p. m. | D. N. a. m. | 1.25 | 9:11 p. m. | 9:59 p. m. | 0.04 | 0.19 | 0.39 | 0.51 | 0.56 | 0.73 | 0.77 | 0.82 | 0.87 | 1.02 | 1.08 | ..... | ..... | ..... | ..... |
| | 23 | 7:29 p. m. | 9:45 p. m. | 0.60 | 7:50 p. m. | 8:08 p. m. | 0.01 | 0.18 | 0.43 | 0.52 | 0.56 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Syracuse, N. Y. | 12 | | | 0.29 | | | | | | | | | | | | | | 0.25 | | | |
| Tacoma, Wash. | 28 | | | 0.07 | | | | | | | | | | | | | | 0.03 | | | |
| Tampa, Fla. | 13 | 5:45 p. m. | 7:15 p. m. | 0.79 | 5:52 p. m. | 6:11 p. m. | 0.01 | 0.12 | 0.30 | 0.49 | 0.65 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 16 | 5:54 p. m. | 7:00 p. m. | 0.87 | 5:54 p. m. | 6:18 p. m. | 0.00 | 0.14 | 0.29 | 0.45 | 0.66 | 0.84 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 18 | 7:14 p. m. | 7:50 p. m. | 0.89 | 7:18 p. m. | 7:38 p. m. | 0.01 | 0.26 | 0.59 | 0.78 | 0.87 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Tatoosh Island, Wash. | 22 | | | 0.08 | | | | | | | | | | | | | | 0.08 | | | |
| Taylor, Tex. | 18 | 5:50 p. m. | 7:48 p. m. | 0.85 | 6:49 p. m. | 7:15 p. m. | 0.05 | 0.15 | 0.31 | 0.45 | 0.57 | 0.68 | 0.72 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Terre Haute, Ind. | 26 | D. N. a. m. | 10:58 a. m. | 2.09 | 4:57 a. m. | 5:16 a. m. | 0.17 | 0.21 | 0.42 | 0.65 | 0.76 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Thomasville, Ga. | 4 | 3:38 p. m. | 7:10 p. m. | 1.81 | 4:29 p. m. | 5:33 p. m. | 0.15 | 0.15 | 0.24 | 0.26 | 0.41 | 0.62 | 0.82 | 0.94 | 1.02 | 1.15 | 1.29 | 1.45 | 1.56 | ..... | ..... |
| | 7 | 12:25 p. m. | 1:20 p. m. | 1.20 | 12:28 p. m. | 12:49 p. m. | 0.01 | 0.18 | 0.32 | 0.77 | 1.14 | 1.18 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 25 | 1:35 p. m. | 5:54 p. m. | 1.20 | 1:50 p. m. | 2:19 p. m. | 0.01 | 0.21 | 0.45 | 0.60 | 0.73 | 0.82 | 0.90 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Toledo, Ohio. | 18 | | | 0.24 | | | | | | | | | | | | | | 0.24 | | | |
| Tonopah, Nev. | 27 | | | 0.22 | | | | | | | | | | | | | | 0.10 | | | |
| Topeka, Kans. | 7 | | | 0.26 | | | | | | | | | | | | | | 0.26 | | | |
| Valentine, Nebr. | 30 | | | 0.38 | | | | | | | | | | | | | | 0.21 | | | |
| Vicksburg, Miss. | 7 | 10:10 p. m. | 11:15 p. m. | 1.61 | 10:13 p. m. | 10:52 p. m. | 0.01 | 0.34 | 0.69 | 0.93 | 1.13 | 1.29 | 1.39 | 1.46 | 1.52 | ..... | ..... | ..... | ..... | ..... | ..... |
| | 20 | 1:31 p. m. | 3:05 p. m. | 0.76 | 1:38 p. m. | 1:58 p. m. | 0.01 | 0.22 | 0.42 | 0.54 | 0.61 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Walla Walla, Wash. | 8 | | | T. | | | | | | | | | | | | | | T. | | | |
| Washington, D. C. | 2 | 5:45 p. m. | 9:20 p. m. | 1.97 | 7:19 p. m. | 8:24 p. m. | 0.36 | 0.11 | 0.22 | 0.38 | 0.43 | 0.53 | 0.58 | 0.61 | 0.77 | 0.85 | 0.99 | 1.27 | 1.53 | ..... | ..... |
| | 14 | 4:30 p. m. | 5:50 p. m. | 1.12 | 4:44 p. m. | 5:00 p. m. | 0.03 | 0.13 | 0.54 | 1.07 | 1.08 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 25 | 10:38 a. m. | 1:55 p. m. | 3.23 | 10:56 a. m. | 11:13 a. m. | 0.02 | 0.18 | 0.45 | 0.70 | 0.79 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | | | | | 12:23 p. m. | 1:25 p. m. | 1.17 | 0.19 | 0.32 | 0.54 | 0.59 | 0.61 | 0.68 | 0.83 | 1.01 | 1.30 | 1.49 | 1.89 | 2.04 | ..... | ..... |
| Wausau, Wis. | 20 | 9:50 a. m. | 12:10 p. m. | 0.68 | 11:08 a. m. | 11:42 a. m. | 0.04 | 0.07 | 0.17 | 0.18 | 0.20 | 0.20 | 0.38 | 0.56 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Wichita, Kans. | 18–19 | D. N. p. m. | D. N. a. m. | 0.87 | 1:33 a. m. | 2:05 a. m. | 0.02 | 0.06 | 0.16 | 0.31 | 0.50 | 0.67 | 0.79 | 0.83 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Williston, N. Dak. | 4 | | | 0.15 | | | | | | | | | | | | | | 0.14 | | | |
| Wilmington, N. C. | 7 | 11:11 a. m. | 1:10 p. m. | 0.91 | 11:56 a. m. | 12:20 p. m. | 0.09 | 0.05 | 0.12 | 0.22 | 0.41 | 0.50 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | | 1:55 p. m. | 3:20 p. m. | 0.72 | 2:02 p. m. | 2:23 p. m. | 0.01 | 0.15 | 0.23 | 0.30 | 0.48 | 0.50 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 8 | 1:20 p. m. | 2:50 p. m. | 0.74 | 1:26 p. m. | 1:54 p. m. | 0.01 | 0.14 | 0.33 | 0.52 | 0.59 | 0.66 | 0.72 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 10 | 12:25 a. m. | 2:20 a. m. | 1.21 | 12:35 a. m. | 1:03 a. m. | 0.01 | 0.10 | 0.23 | 0.51 | 0.83 | 1.11 | 1.16 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 21 | 9:58 a. m. | 11:05 a. m. | 1.35 | 10:00 a. m. | 10:30 a. m. | 0.01 | 0.21 | 0.40 | 0.50 | 0.77 | 0.99 | 1.18 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 27 | 2:26 p. m. | 3:36 p. m. | 0.72 | 2:27 p. m. | 2:58 p. m. | 0.01 | 0.24 | 0.29 | 0.32 | 0.37 | 0.42 | 0.57 | 0.59 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 27 | 4:05 p. m. | 7:25 p. m. | 1.38 | 5:54 p. m. | 6:24 p. m. | 0.27 | 0.32 | 0.50 | 0.75 | 0.92 | 0.98 | 1.06 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Winnemucca, Nev. | 7 | | | 0.03 | | | | | | | | | | | | | | 0.03 | | | |
| Wytheville, Va. | 16 | | | 0.82 | | | | | | | | | | | | | | 0.62 | | | |
| Yankton, S. Dak. | 21 | 9:30 p. m. | 10:40 p. m. | 1.02 | 9:34 p. m. | 10:07 p. m. | 0.02 | 0.15 | 0.31 | 0.60 | 0.80 | 0.82 | 0.92 | 0.99 | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Yellowstone Park, Wyo. | 22 | | | 0.21 | | | | | | | | | | | | | | 0.21 | | | |

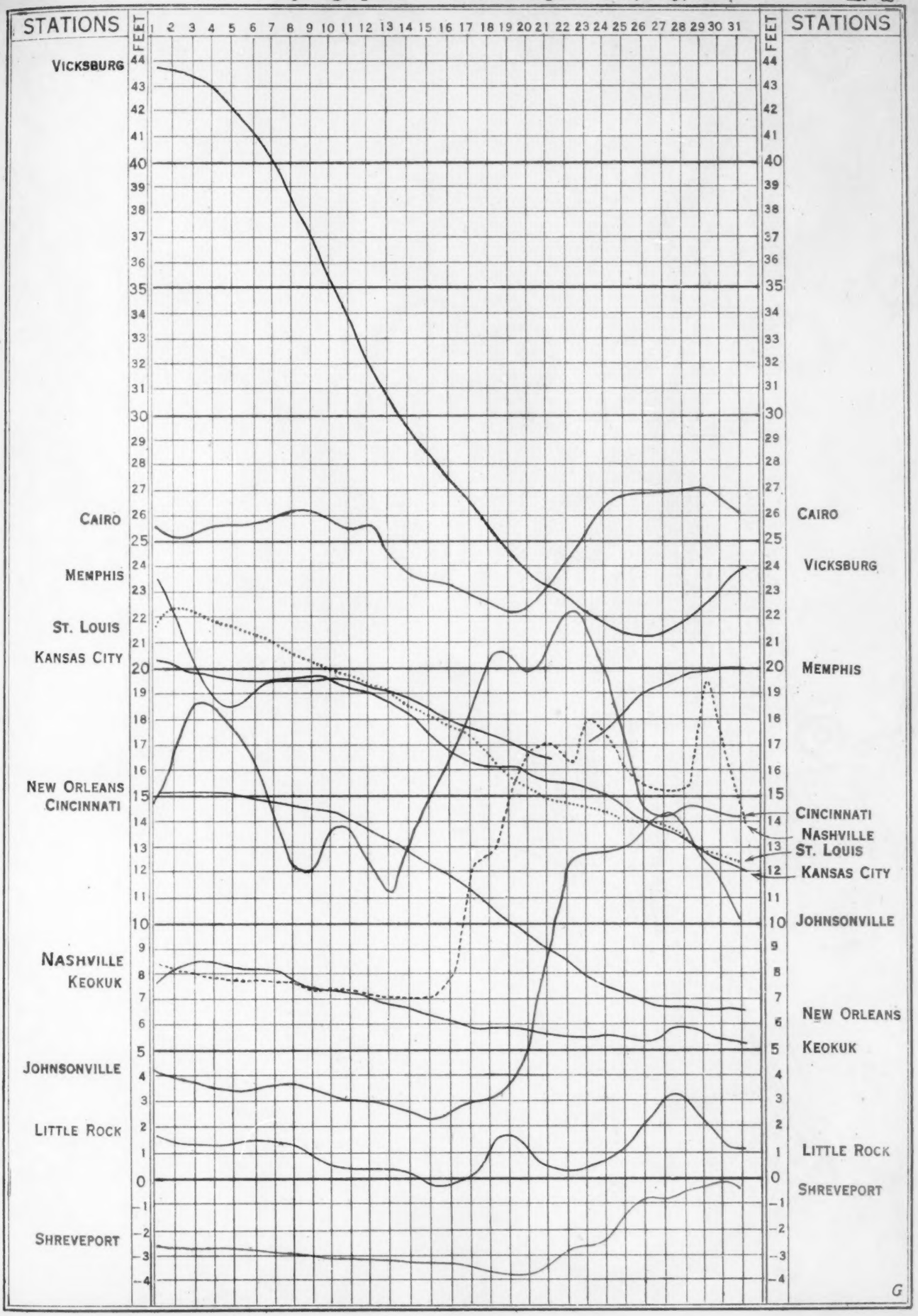
* Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE III.—*Data furnished by the Canadian Meteorological Service, July, 1917.*

| Stations. | Altitude above M. S. L.* Jan. 1, 1916. | Pressure. | | | Temperature. | | | | | | Precipitation. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Station, reduced to mean of 24 hours. | Sealevel, reduced to mean of 24 hours. | Departure from normal. | Mean max.+ mean min.÷2. | Departure from normal. | Mean maximum. | Mean minimum. | Highest. | Lowest. | Total. | Departure from normal. | Total snowfall. |
| | *Feet.* | *Inches.* | *Inches.* | *Inches.* | °*F.* | °*F.* | °*F.* | °*F.* | °*F.* | °*F.* | *Inches.* | *Inches.* | *Inches.* |
| St. Johns, N. F. | 125 | 29.70 | 29.83 | −0.14 | 59.2 | −0.1 | 66.6 | 51.9 | 83 | 45 | 2.63 | −1.26 | |
| Sydney, C. B. I. | 48 | 29.91 | 29.95 | + .02 | 63.3 | +1.0 | 74.2 | 52.5 | 89 | 43 | 4.58 | +0.93 | |
| Halifax, N. S. | 88 | 29.84 | 29.94 | − .02 | 64.9 | +1.5 | 74.2 | 55.6 | 86 | 49 | 2.37 | −1.68 | |
| Yarmouth, N. S. | 65 | 29.87 | 29.94 | − .01 | 58.9 | −0.6 | 66.0 | 51.8 | 80 | 47 | 1.86 | −1.76 | |
| Charlottetown, P. E. I. | 38 | 29.88 | 29.92 | + .02 | 66.7 | +2.6 | 74.3 | 59.1 | 97 | 53 | 1.68 | −1.81 | |
| Chatham, N. B. | 28 | 29.89 | 29.91 | +0.03 | 67.2 | +2.2 | 76.2 | 58.2 | 94 | 47 | 2.88 | −1.31 | |
| Father Point, Que. | 20 | 29.86 | 29.88 | + .03 | 58.1 | +0.5 | 65.5 | 50.8 | 76 | 42 | 2.21 | −0.83 | |
| Quebec, Que. | 296 | 29.60 | 29.92 | + .01 | 67.3 | +1.8 | 76.4 | 58.3 | 88 | 52 | 4.10 | −0.16 | |
| Montreal, Que. | 187 | 29.71 | 29.91 | − .02 | 71.5 | +3.0 | 79.9 | 63.0 | 93 | 54 | 4.46 | +0.17 | |
| Stonecliffe, Ont. | 489 | 29.28 | 29.88 | − .06 | 70.9 | +5.3 | 79.0 | 62.8 | 94 | 52 | 2.32 | −0.80 | |
| Ottawa, Ont. | 236 | 29.64 | 29.90 | −0.04 | 70.0 | +0.5 | 79.2 | 60.9 | 98 | 51 | 3.33 | −0.14 | |
| Kingston, Ont. | 285 | 29.62 | 29.92 | − .05 | 68.2 | 0.0 | 75.1 | 61.4 | 88 | 51 | 1.23 | −1.66 | |
| Toronto, Ont. | 379 | 29.51 | 29.90 | − .07 | 70.4 | +2.4 | 80.1 | 60.7 | 98 | 49 | 3.58 | +0.66 | |
| White River, Ont. | 1,244 | 28.56 | 29.85 | − .09 | 61.2 | +1.7 | 74.4 | 48.1 | 91 | 31 | 3.46 | +0.66 | |
| Port Stanley, Ont. | 592 | 29.31 | 29.94 | − .04 | 67.5 | −0.3 | 75.5 | 59.6 | 90 | 47 | 2.19 | −0.85 | |
| Southampton, Ont. | 656 | 29.22 | | | 65.9 | +1.2 | 73.6 | 58.3 | 94 | 45 | 4.23 | +2.25 | |
| Parry Sound, Ont. | 688 | 29.23 | 29.91 | −0.05 | 67.6 | +1.6 | 77.1 | 58.1 | 93 | 45 | 3.23 | +0.61 | |
| Port Arthur, Ont. | 644 | 29.18 | 29.89 | − .05 | 64.0 | +2.0 | 73.0 | 55.0 | 89 | 44 | 1.45 | −2.03 | |
| Winnipeg, Man. | 760 | 29.04 | 29.85 | − .08 | 69.1 | +3.1 | 81.0 | 57.2 | 93 | 42 | 3.27 | +0.21 | |
| Minnedosa, Man. | 1,690 | 28.09 | 29.86 | − .07 | 67.5 | +5.3 | 82.9 | 52.0 | 99 | 32 | 0.80 | −1.80 | |
| Qu'Appelle, Sask. | 2,115 | 27.62 | 29.81 | −0.11 | 66.5 | +3.0 | 80.5 | 52.6 | 102 | 34 | 0.73 | −1.75 | |
| Medicine Hat, Alberta | 2,144 | 27.56 | 29.77 | − .13 | 74.7 | +6.9 | 92.0 | 57.4 | 101 | 46 | 0.52 | −1.57 | |
| Swift Current, Sask. | 2,392 | 27.31 | 29.80 | − .11 | 69.7 | +3.2 | 86.3 | 53.1 | 100 | 41 | 0.70 | −1.74 | |
| Calgary, Alberta | 3,428 | 26.39 | 29.84 | − .06 | 64.5 | +3.9 | 82.2 | 46.9 | 91 | 34 | 0.47 | −2.21 | |
| Banff, Alberta | 4,521 | 25.38 | 29.86 | − .04 | 60.5 | +3.9 | 77.9 | 43.0 | 90 | 35 | 0.46 | −2.78 | |
| Edmonton, Alberta | 2,150 | | | | 67.0 | +5.1 | 80.7 | 53.3 | 92 | 42 | 0.35 | −1.70 | |
| Prince Albert, Sask. | 1,450 | 28.28 | 29.80 | −0.11 | 67.3 | +2.6 | 82.5 | 52.0 | 94 | 40 | 0.79 | −1.55 | |
| Battleford, Sask. | 1,592 | 28.12 | 29.82 | − .08 | 70.8 | +2.3 | 86.1 | 55.4 | 98 | 44 | 0.11 | −1.50 | |
| Kamloops, B. C. | 1,262 | 28.67 | 29.93 | − .01 | 58.8 | −1.2 | 67.0 | 50.5 | 81 | 49 | 0.16 | −0.24 | |
| Victoria, B. C. | 230 | 29.79 | 30.04 | − .01 | | | | | | | | | |
| Barkerville, B. C. | 4,180 | 25.72 | 30.00 | +0.09 | 51.7 | −3.4 | 63.8 | 39.5 | 76 | 32 | 4.22 | +1.20 | |
| Hamilton, Bermuda | 151 | 30.07 | 30.23 | + .09 | 78.3 | 0.4 | 83.2 | 73.5 | 87 | 71 | 3.00 | −1.44 | |

* *See* Explanation of Tables in this REVIEW for July, 1917, page 388.

Chart I. **Hydrographs of Several Principal Rivers, July, 1917.**


STATIONS
FEET
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 −1 −2 −3 −4
VICKSBURG
CAIRO
MEMPHIS
ST. LOUIS
KANSAS CITY
NEW ORLEANS
CINCINNATI
NASHVILLE
KEOKUK
JOHNSONVILLE
LITTLE ROCK
SHREVEPORT
CINCINNATI
NASHVILLE
ST. LOUIS
KANSAS CITY
G

## Chart II. Tracks of Centers of High Areas, July, 1917.

(Plotted by Charles A. Donnel.)

## Chart III. Tracks of Centers of Low Areas, July, 1917.

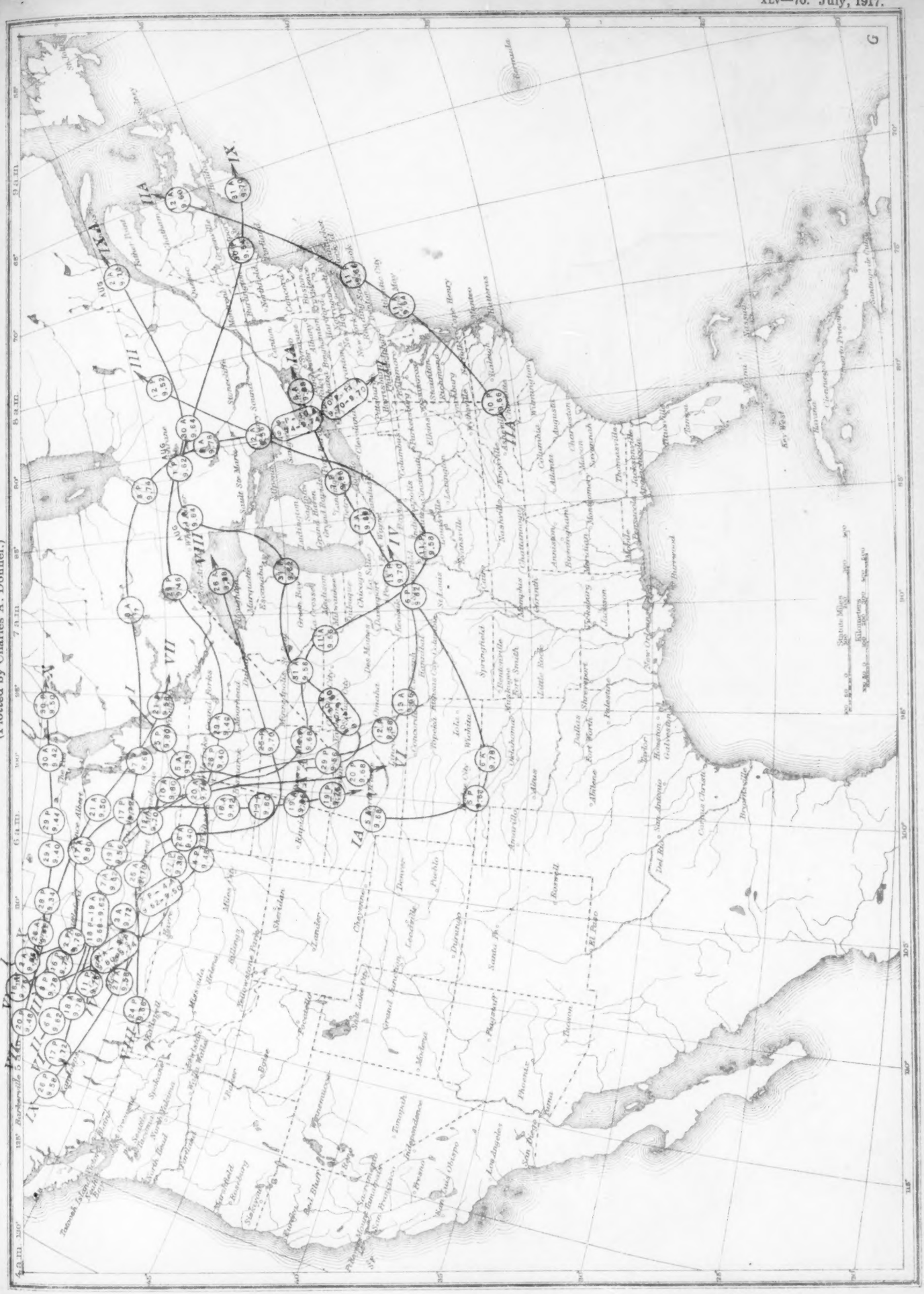


**Chart III. Tracks of Centers of Low Areas, July, 1917.**
(Plotted by Charles A. Donnel.)

## Chart IV. Departure (°F.) of the Mean Temperature from the Normal, July, 1917.

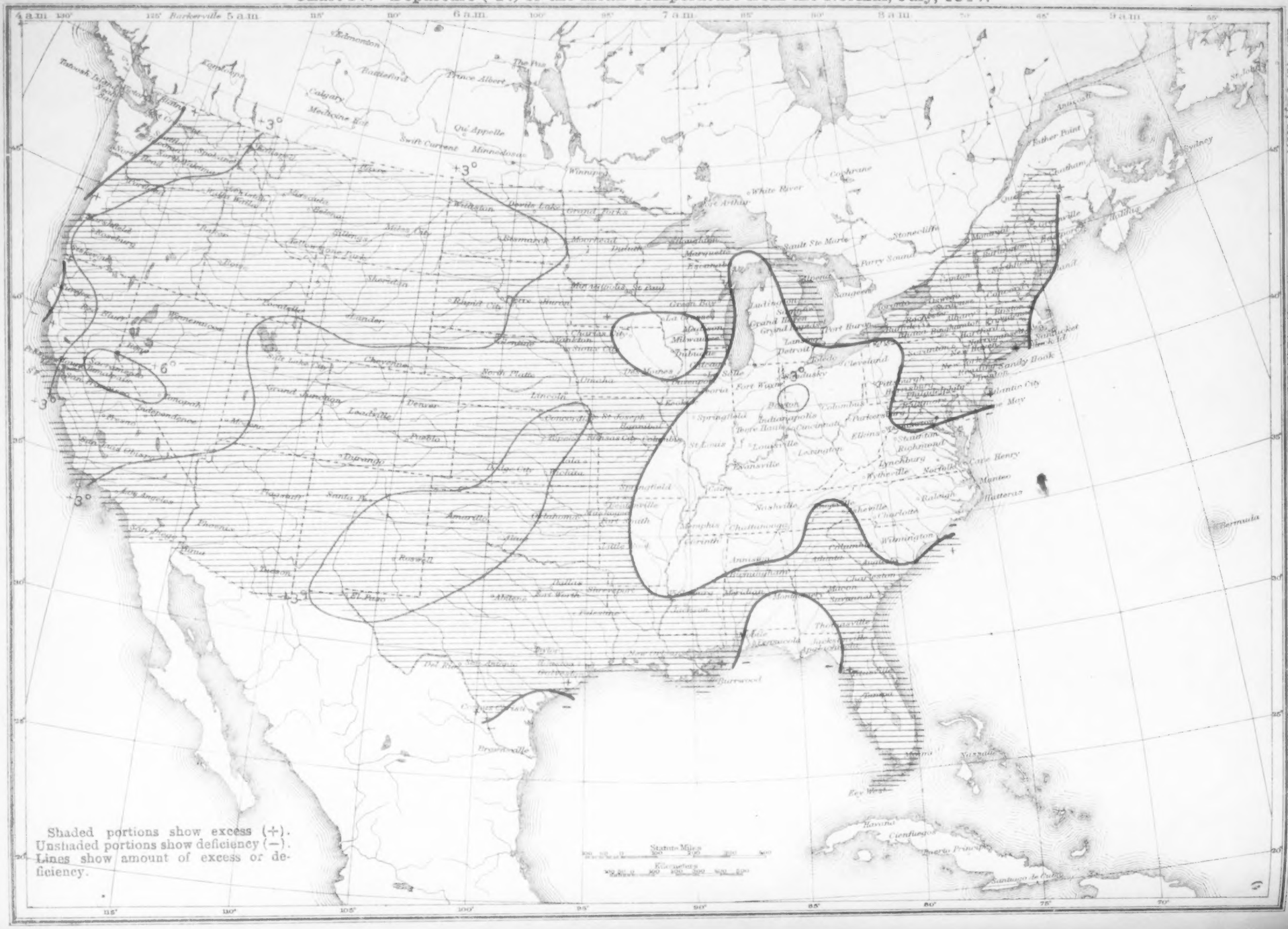


Chart V. Total Precipitation, July, 1917.
NO RAIN
NO RAIN
NO RAIN
Scale of Shades.
0 to 2 inches.
2 to 4 inches.
4 to 6 inches.
6 to 8 inches.
Over 8 inches.
Statute Miles
Kilometers
F

## Chart VI. Percentage of Clear Sky between Sunrise and Sunset, July, 1917.

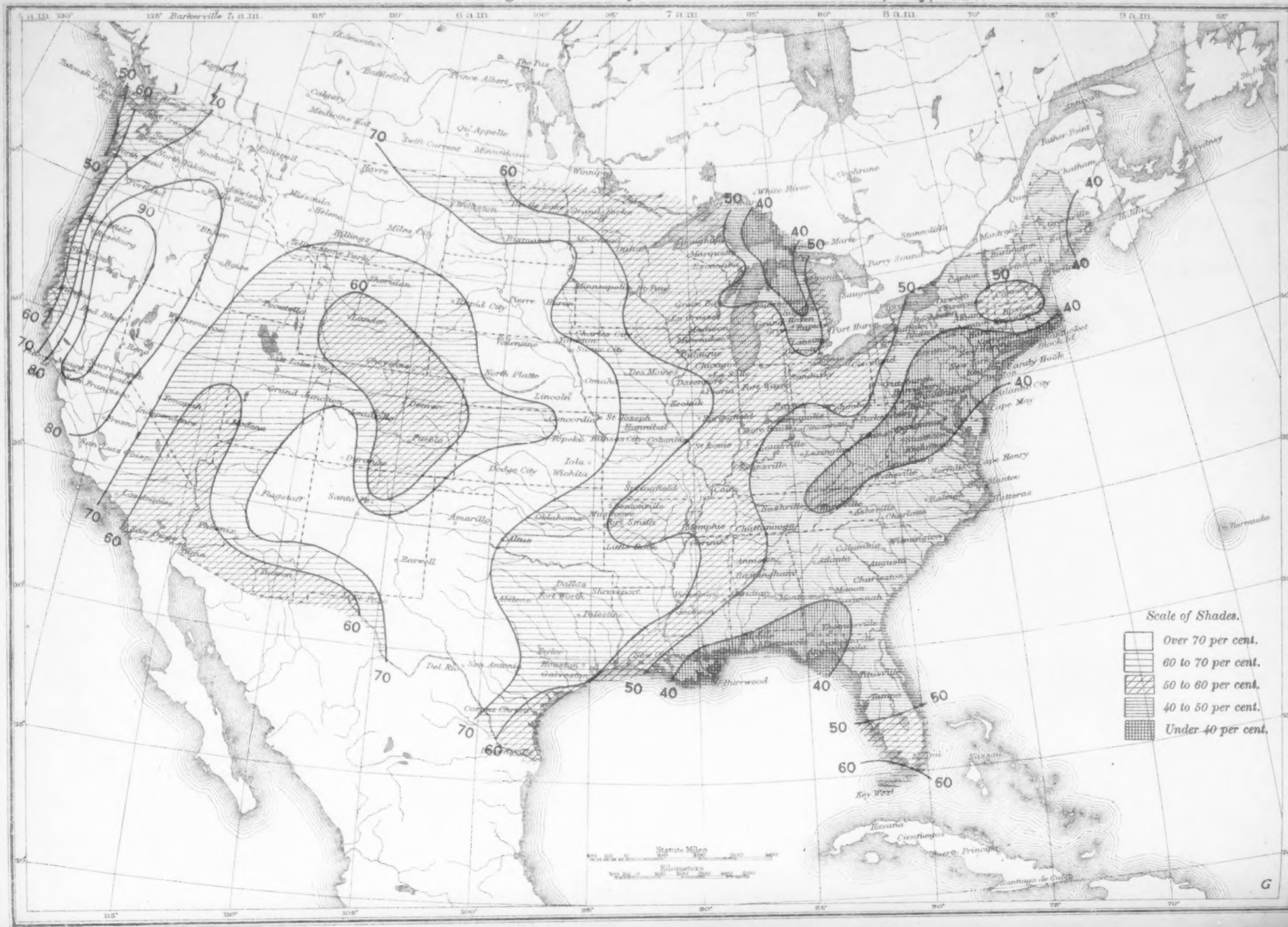
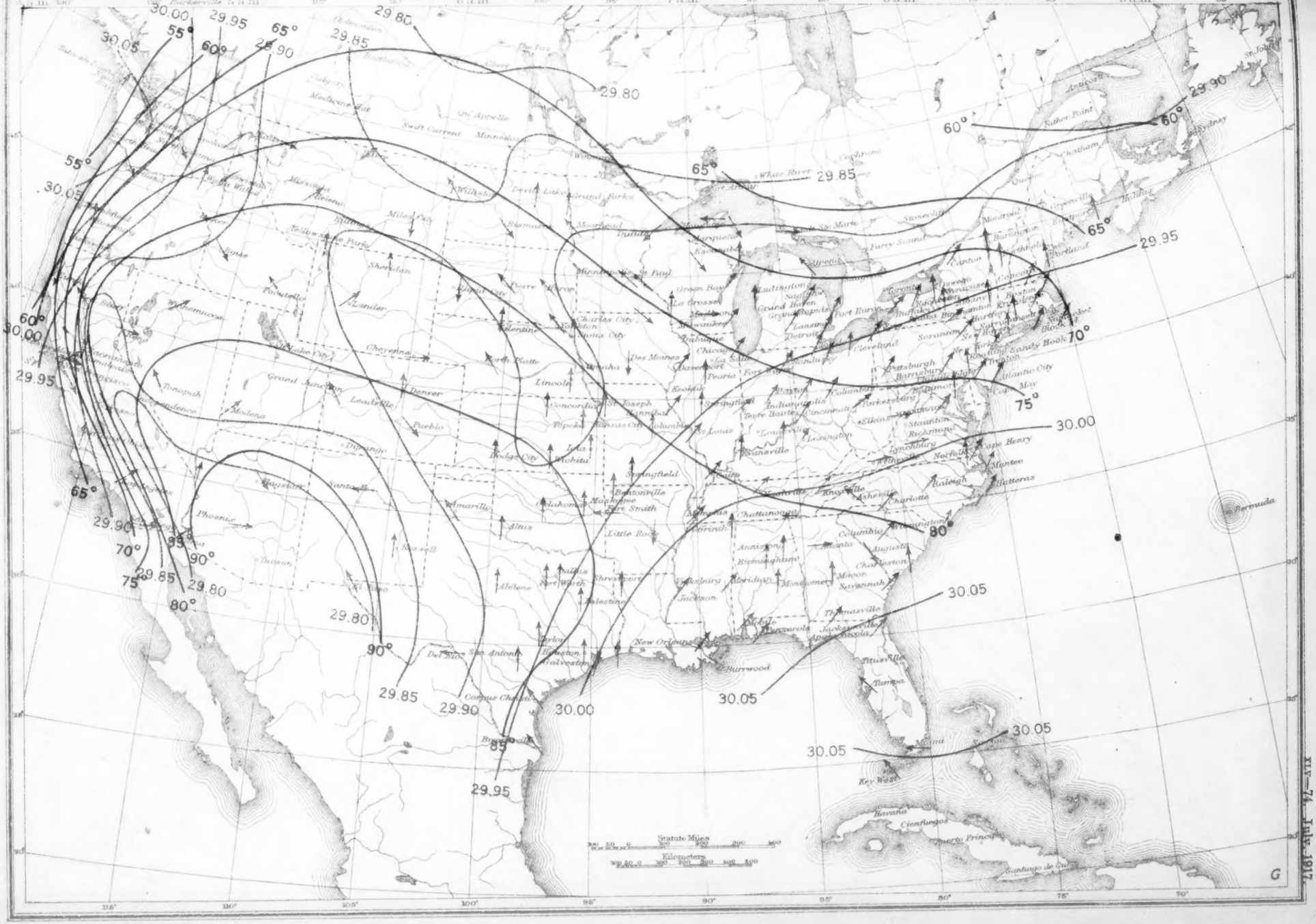
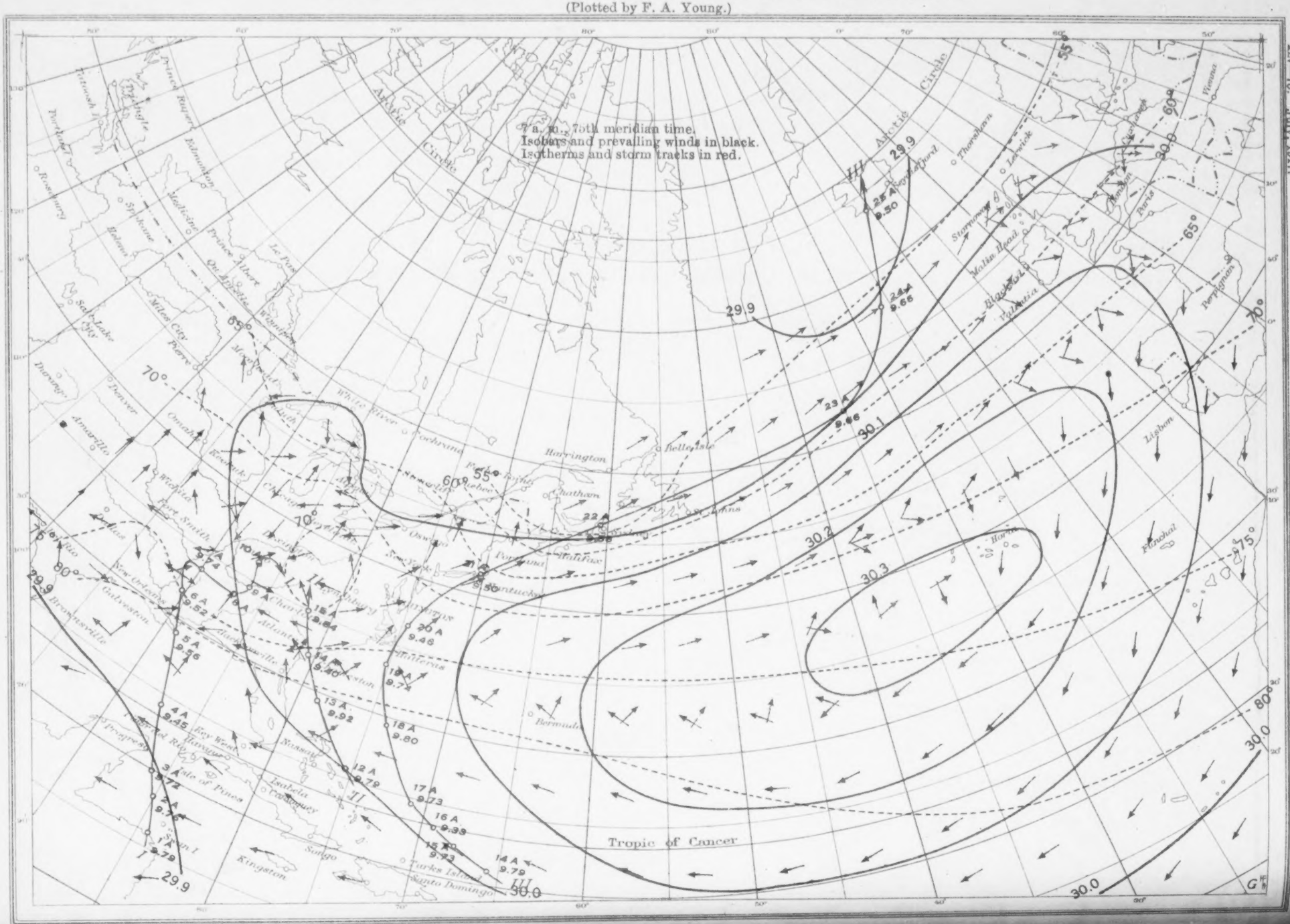


**Chart VII. Isobars and Isotherms at Sea Level; Prevailing Winds, July, 1917.**



## Chart IX. Means of Meteorological Data for North Atlantic Ocean, July, 1916.

(Plotted by F. A. Young.)



ADVANCE SHEET 1
JAN. 1917

UNITED STATES DEPARTMENT OF AGRICULTURE
WEATHER BUREAU, CHARLES F. MARVIN, CHIEF

# AVERAGE ANNUAL PRECIPITATION IN

BASED ON RECORDS OF ABOUT 1600 STATIONS FOR THE 20-YEAR PERIOD 1895-1914, AND 2000
5 TO 19 YEARS IN LENGTH, UNIFORMLY ADJUSTED TO THE SAME PERIO

WASHINGTON, D. C.

# STATES DEPARTMENT OF AGRICULTURE
## THER BUREAU, CHARLES F. MARVIN, CHIEF
# NNUAL PRECIPITATION IN INCHES
STATIONS FOR THE 20-YEAR PERIOD 1895-1914, AND 2000 ADDITIONAL RECORDS, FROM ARS IN LENGTH, UNIFORMLY ADJUSTED TO THE SAME PERIOD.

WASHINGTON, D. C.

SCALE OF SHADES

- UNDER 10 INCHES
- 10 TO 15 INCHES
- 15 TO 20 INCHES
- 20 TO 30 INCHES
- 30 TO 40 INCHES

20 TO 30 INCHES

30 TO 40 INCHES

40 TO 50 INCHES

PERCENTAGE OF ANNUAL PRECIPITATION
OCCURRING BETWEEN APR. 1 AND SEPT. 30

SCALE OF SHADES
UNDER 20 %
20 - 40 %
40 - 60 %
60 - 80 %
OVER 80 %

Compiled from the records of about 1,600 stations 1895-1914

PERIO

NEW
CENTR
NORT
OHIO
MISS
GULF
NORT
SOUT
SNAK
ARIZ
WILL
CENT

99 Longitude West 97 of Greenwich 95

SCALE OF SHADES

- UNDER 10 INCHES
- 10 TO 15 INCHES
- 15 TO 20 INCHES
- 20 TO 30 INCHES
- 30 TO 40 INCHES
- 40 TO 50 INCHES
- 50 TO 60 INCHES
- OVER 60 INCHES

PERIOD WITHIN WHICH 50% OF THE ANNUAL PRECIPITATION OCCURS

| REGIONS | JAN. | FEB. | MAR. | APR. | MAY | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. | DEC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NEW YORK LAKE REGION | | | | | | | ■ | ■ | ■ | ■ | ■ | |
| CENTRAL VIRGINIA | | | | | ■ | ■ | ■ | ■ | | | | |
| NORTHERN FLORIDA | | | | | | ■ | ■ | ■ | ■ | | | |
| OHIO | | | | ■ | ■ | ■ | ■ | | | | | |
| MISSOURI | | | | | | ■ | ■ | ■ | ■ | | | |
| GULF COAST | ■ | ■ | ■ | ■ | | | | | | | | ■ |
| NORTHERN GREAT PLAINS | | | | | ■ | ■ | ■ | | | | | |
| SOUTHERN GREAT PLAINS | | | | ■ | ■ | ■ | ■ | ■ | | | | |
| SNAKE RIVER REGION | ■ | ■ | ■ | | | | | | | | ■ | ■ |
| ARIZONA | | | | | | | ■ | ■ | ■ | ■ | | |
| WILLAMETTE VALLEY | ■ | ■ | | | | | | | | | ■ | ■ |
| CENTRAL CALIFORNIA | ■ | ■ | ■ | | | | | | | | | ■ |

- ○ Regular Weather Bureau Stations
- • Cooperative Weather Bureau Stations
- × Agricultural Colleges
- ⊡ Regular Weather Bureau Stations and Agric. Colleges
- ⊠ Cooperative Weather Bureau Stations and Agric. Colleges
- ✡ Capitals, Regular Weather Bureau Stations
- ✡ Capitals, Reg. Weather Bureau Sta. and Agric. Colleges
- ✱ Capitals, Cooperative Weather Bureau Stations

PREPARED BY JOSEPH BURTON KINCER, 1916

POLYCONIC PROJECTION. TOPOGRAPHY COMPILED AND DRAWN FROM DATA FURNISHED BY U. S. GEOL. SURVEY BY F. J. MARSCHNER, OFFICE OF FARM MANAGEMENT, 1915

Scale 1:8,000,000

Kilometers 100 0 100 200 300 400 500

Statute Miles 100 0 100 200 300

99 Longitude West 97 of Greenwich 95 93 91 89 87 85 83 81 79 77 75

41 39 37 35 33 31 29 27 25 23

ENGRAVED AND PRINTED BY THE U. S GEOLOGICAL SURVEY